CONVERSION TABLE (1)

Magnetic Course.	Deviation.	Compass Course.	Magnetic Course.	Deviation.	Compass Course.
N 0°	0	0	S 180°	2°E	18
10°	1°W	1	190°	3°E	19
20°	2°W	2	200°	4°E	20
30°	3°W	3	210°	5°E	21
40°	4°W	4	220°	6°E	22
NE			SW		
50°	4°W	5	230°	6°E	23
60°	3°W	6	240°	4°E	24
70°	2°W	7	250°	2°E	25
80°	1°W	8	260°	0°	26
E 90°	1°W	9	W 270°	2°W	27
100°	1°E	10	280°	1°W	28
110°	2°E	11	290°	0°	29
120°	3°E	12	300°	1°E	30
130°	4°E	13	310°	2°E	31
SE			NW		
140°	5°E	14	320°	3°E	32
150°	5°E	15	330°	3°E	33
160°	4°E	16	340°	2°E	34
170°	3°E	17	350°	1°E	35
S 180°	2°E	18	360°	0°	36

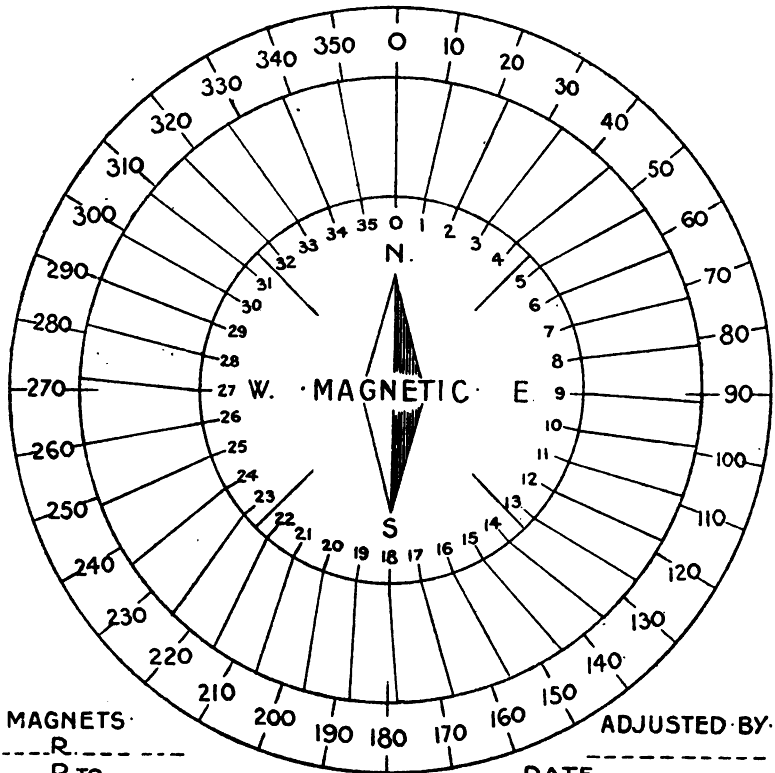
CONVERSION TABLE (2)

·MACKENZIE·
AERO · DEVIATION · CARD ·

·STATION·

Nº________

·COMPASS·

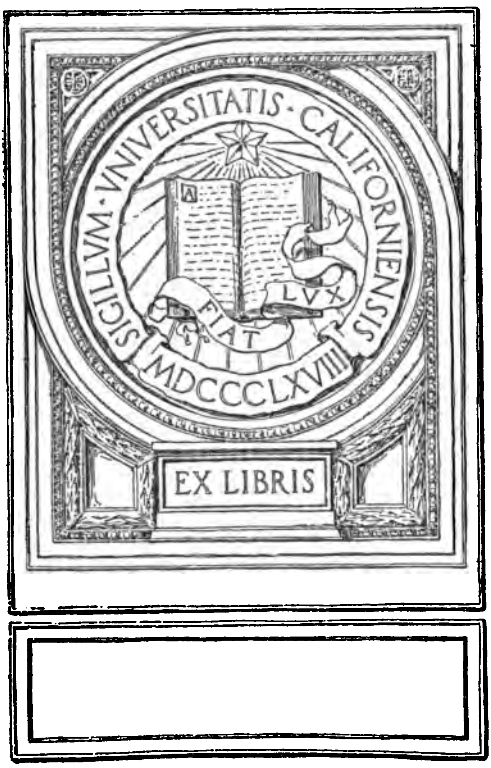


MAGNETS·
____R.______
___R.TO ____

ADJUSTED·BY·
____
DATE.________

·TO · USE · CARD·

AFTER · ASCERTAINING · DEVIATION · DRAW
LINES · FROM · MAGNETIC · COURSE · TO · MAKE · GOOD
TO · COMPASS · COURSE · TO · STEER ·


SIGILLVM · VNIVERSITATIS · CALIFORNIENSIS
FIAT LVX
MDCCCLXVIII
EX LIBRIS

AIR NAVIGATION

NOTES AND EXAMPLES

AIR NAVIGATION

NOTES AND EXAMPLES

BY

INSTRUCTOR CAPTAIN S. F. CARD, B.A., R.N.

HEAD OF THE NAVIGATION DEPARTMENT AT THE
ROYAL NAVAL COLLEGE, GREENWICH

NEW YORK:
LONGMANS, GREEN & CO.
LONDON: EDWARD ARNOLD
1919

PREFACE

THE encouragement given to the study of Air Navigation by Brigadier-General H. D. Briggs, R.A.F., with whom, when he was Director of Training, I was associated for the purpose of the education of Pilots and Observers, led to the navigation courses outlined in this book.

The methods adopted and the order in which the various items are dealt with, are those which proved to be the most effective in the opinion of the large staff of trained Instructors at the Royal Naval College, Greenwich, who dealt with this subject, being based on the experience gained from instructing many hundreds of Officers of the Flying Services.

The subject has been treated in a very elementary manner, and it will be found that common sense and a little knowledge of arithmetic are sufficient for all the problems dealt with, though one or two of the *proofs* require a slight acquaintance with geometry.

For laying down courses and bearings on the map, a Douglas Protractor will be found simple, efficient and inexpensive, but if expense is not considered, the Bigsworth Protractor is by far the best instrument. The chapter on Wind and Weather is only fragmentary, and requires amplification by the Instructor; the important matters of map reading and choice of objects for checking the route, cannot be dealt with satisfactorily in a book.

So many have assisted me with suggestions and in compiling and checking the numerous examples, that individual acknowledgement is out of the question; without their help, these "notes" would not have had the success that has attended their use in the strenuous period which is now only a memory.

S. F. CARD.

LONDON,
May, 1919.

CONTENTS

* *Extra copies of the Skeleton Map and Chart may be obtained from the Publishers.*

Portions marked with a black marginal line are only required for sea work.

Any map can be used which contains the places dealt with in any question, but the answers may differ slightly from those given, as for the sake of accuracy, the town is represented by a point on the skeleton map supplied.

Any chart of the southern portion of the North Sea can be used, but since the positions of lightships are often not quite the same in different editions of charts, it is advisable to note (by the latitude and longitude) whether the positions of the Lights, etc. in the question correspond with those on the skeleton chart supplied.

CHAPTER I

THE MEASUREMENT OF DISTANCE

Distance on the Earth

The earth may be considered a sphere of about 8000 land miles in diameter.

It rotates about a certain diameter called the axis.

Any plane through the centre cuts the surface in **a great circle**; any plane not passing through the centre cuts it in **a small circle**.

The shortest route from one place to another is along the great circle joining them.

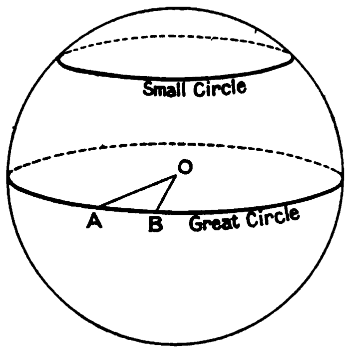


Fig. 1

The length of a great circle arc is measured by the angle it subtends at the centre: thus if the angle AOB in Fig. 1 is 30°, the arc AB is 30°. Each degree is divided into 60 parts called minutes (written ′). Thus 1° = 60′.

The length of 1′ of a great circle is called a **sea or nautical mile**, and is taken as 6080 feet, whereas a land mile is 5280 feet.

A **cable** is $\frac{1}{10}$th of a sea mile. In practice it is taken as 200 yards.

A speed of one sea mile per hour is called a **knot**.

Note. 60 knots = about 100 feet per second, 60 miles per hour = 88 feet per second.

To turn sea miles into land miles or knots into m.p.h. } add $\frac{1}{7}$th of the number.

To turn land miles into sea miles or m.p.h. into knots } subtract $\frac{1}{8}$th of the number.

Examples 1

(1) Express the following speeds in knots:—80 m.p.h.; 56 m.p.h.; 120 m.p.h.; 50 m.p.h.; 27 m.p.h.; 1100 f.s.

(2) The following speeds are in knots, express them in miles per hour:—70; 63; 21; 90; 110; 40; 52.

(3) How many nautical miles are there in a great circle? How many hours would it take to travel round a great circle at 90 knots?

(4) Find the time taken at 65 knots to fly 200 land miles.

(5) Find the time to fly 300 sea miles at 100 miles per hour.

The position of an aircraft is that of the point on the earth directly beneath it, and this is fixed on the map or chart by latitude and longitude.

The meanings of the terms "Latitude," "Longitude," "True meridians" and "Parallels of Latitude" are shown in Fig. 2.

The line joining P and P′ is the axis of the earth.

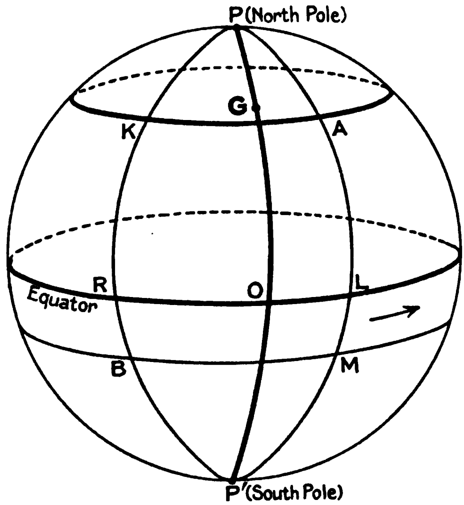


Fig. 2

G is Greenwich.

A and B are two places.

PAP′, PBP′ are the true meridians of A and B.

PGP′ is the true meridian of Greenwich.

OL is the Longitude of A (East).

OR is the Longitude of B (West).

LA is the Latitude of A (North).

RB is the Latitude of B (South).

AK and BM are the parallels of Latitude of A and B.

The earth rotates in the direction shown by the arrow; this is called "Eastwards," and in consequence the heavens appear to rotate Westwards.

Note. The following definitions are given for reference, if required.

The Poles are the ends of the axis.

The Equator is the great circle midway between the Poles.

True Meridians are semi-great circles joining the Poles, and cut the equator at right angles.

The Longitude of a place is the arc of the equator from the meridian of Greenwich to the meridian of the place, and is measured from 0° to 180° east or west of Greenwich..

The Latitude of a place is its distance North or South of the Equator.

Parallels of Latitude are small circles parallel to the Equator.

The Pole Star is very nearly directly over the North Pole of the earth, so that when facing the Pole Star you are looking nearly true North; East is on the right hand, and West on the left.

This star is easily found by producing the line joining the pointers of the "Great Bear" or "Charles' Wain," to about five times the distance between them. See Fig. 3.

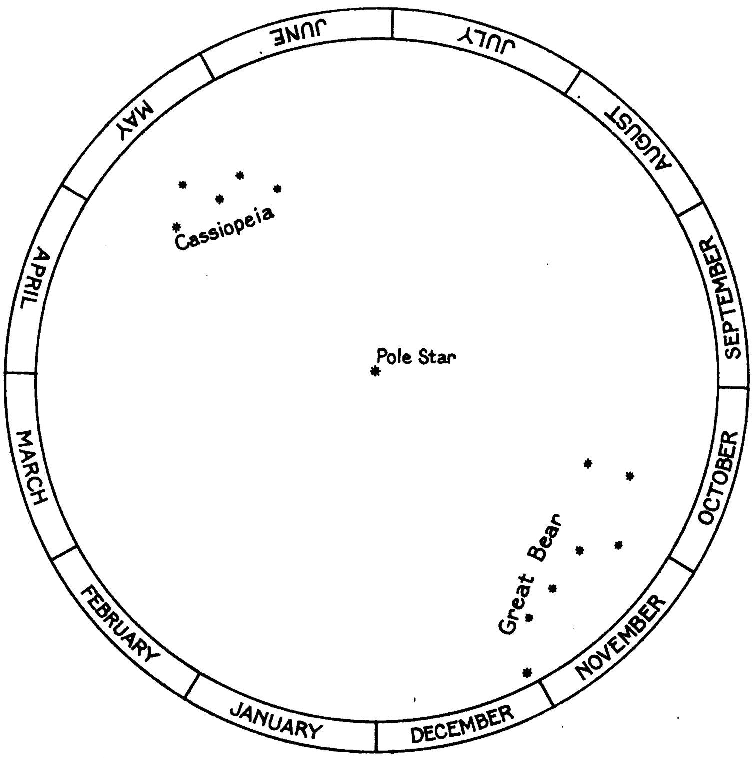


Fig. 3

The constellation of Cassiopeia, which forms a rough W, is about the same distance from the North Pole as the Great Bear.

The rough position of these two constellations at 9 p.m. on any date can be seen by holding the page so that the date is at the lowest point. For any other hour, treat every two hours after 9 p.m. as equivalent to one month later in the year.

Thus for 11 p.m. Aug, 10th hold the page so that Sept. 10th is the lowest point.

Examples 2

(1) The latitude of Greenwich is about 51° N., write down the rough latitudes and longitudes of all the points lettered in Fig. 2.

(2) Draw a circle to represent the earth, put in the poles, the equator, and the meridian of Greenwich, and show on it the rough positions of the following places:—

Vienna (48° N., 16° E.).
Bagdad (33° N., 44° E.).
Petrograd (60° N., 31° E.).
Aden (13° N., 45° E.).
Galway (53° N., 9° W.).
Buenos Aires (35° S., 58° W.).
New York (41° N., 74° W.).

Maps and Charts

Both on maps and charts (which are maps of the sea), the latitude is shown at the sides, and the longitude at the top and bottom. From the bottom of the map or chart to the top, is going north.

Until large distances have to be considered, the straight line joining the two places can be taken to represent the great circle arc between them, i.e. the shortest distance.

On Ordnance Maps, it is sufficiently accurate for air navigation, when dealing only with short distances, to consider that the meridians and parallels of latitude are sets of parallel straight lines. Distance is measured in land miles from the scale given on the map.

Note. The side lines of a map are not generally true meridians. Air maps are frequently divided into squares.

On Charts, true meridians are parallel straight lines, and parallels of latitude are straight lines at right angles to the meridians. Distance on charts is always measured from the scale of latitude at the side, and is in sea miles. If the chart is on a small scale, the scale of latitude, and therefore of distance, may vary a good deal, and hence the distance should always be taken from the latitude scale roughly abreast of the two places.

Note. Distance must never be measured from the scale of longitude at the top or bottom of the chart.

Measuring the Distance

Distances can be measured either by dividers or by putting a centre line of the Douglas Protractor to pass over the places, noting the number of divisions and referring this length to the scale of miles on the map, or, if on a chart, to the latitude scale at the side.

Note 1. If the distance is inconveniently long, join the places by a straight line (by eye), mark some point or points on it, and measure the various portions.

Note 2. If the map is on the scale of 10 miles to 1 inch, the numbers on the 10 inch Douglas Protractor give the correct distance in miles. In these and in future calculations, it should be borne in mind that great accuracy is at present unattainable in Air Navigation; only rough results are to be expected.

Examples 3 (*Map*)

(1) Give the distances of Greenwich from Kingston, Oxford, and Cambridge.

(2) Give the distances of Reading from Leicester, Peterborough, Grantham, and Cranwell.

Examples 4 (*Chart*)

(1) Give the distance in nautical miles from the N. Hinder Lt. to Ostend, Steen Bank Lt. and Would Lt.

(2) Give the distance in nautical miles from Middlekercke Lt. to the Kentish Knock Lt., Ramsgate, Folkestone, and Sheerness.

Plotting a Position by its Latitude and Longitude

Place the Douglas Protractor square on the chart with one edge on the given latitude (marked at the side of the chart), seeing that some meridian coincides with one of the lines on the Protractor. Rule in a short line, say half an inch, at about the given longitude, judging its position by eye. Now place the edge of the protractor on the given longitude (marked at the top or bottom), seeing that some parallel of latitude coincides with one of the lines, and draw a short line to cut the first.

The centre of this cross is the position required.

To take off the latitude and longitude of a point, proceed in a similar way, putting the edge over the point.

Examples 5 (*Chart*)

Plot the given position and find the distance from it to the towns named in the question, by measurement from the chart.

(1) 53° N., 1° 30′ E. to Harwich.
(2) 52° 40′ N., 3° E. to Ostend and to Aldeburgh.
(3) 50° 55′ N., 1° 20′ E. to Colchester and to Ashford.
(4) 52° 5′ N., 2° 25′ E. to Yarmouth and to Wells.
(5) 53° 10′ N., 2° 50′ E. to Lowestoft and to Orford.
(6) 52° 55′ N., 3° 25′ E. to Cromer and to Dungeness.
(7) 50° 53′ N., 0° 55′ E. to Cape Grisnez.

Track and Ground Speed

The straight line on the map or chart joining the two places will be called the **desired track**.

The speed at which an aircraft is covering the ground is called the **ground speed**. It can be found by noting the time elapsing between being over two (visible) objects whose distance apart is known from the map.

Example 1 (*Map*). At a certain moment the aircraft is directly over Kingston, and $8\frac{1}{2}$ minutes later is over Greenwich. What is the ground speed?

By measurement from the map the distance from Greenwich to Kingston is 13 miles.

In $8\frac{1}{2}$ minutes the aeroplane covers 13 miles of ground.

60 „ „ „ $13 \times \frac{60}{8\frac{1}{2}} = \frac{13 \times 60 \times 2}{17} = 92$ miles.

The observed ground speed is therefore 92 m.p.h.

Note. In day flying it is simpler to take the distance travelled in 6 minutes and multiply by 10, or in 10 minutes and multiply by 6.

Example 2 (*Chart*). 5 m. 20 s. after being over Ostend, the aeroplane is over Nieuport. What was the ground speed?

From the chart the distance is $7\frac{1}{2}$ nautical miles.

In $5\frac{1}{3}$ minutes the aeroplane flies $7\frac{1}{2}$ nautical miles.

60 „ „ „ $\frac{7\frac{1}{2} \times 60}{5\frac{1}{3}}$ or roughly 85 nautical miles.

The observed ground speed is therefore 85 knots (or 98 m.p.h.).

Note. By means of instruments in the aircraft, the ground speed can be found from tables without calculation.

Examples 6 (*Map*)

(A) Find the approximate time taken in each case.

(B) Using the answer from (A) instead of the last column, calculate the actual ground speed.

	From	To	Ground speed
(1)	Cranwell	Peterborough	65 m.p.h.
(2)	Nottingham	Bedford	92 m.p.h.
(3)	Cambridge	Derby	100 m.p.h.
(4)	Reading	Peterborough	55 m.p.h.
(5)	Oxford	Cranwell	73 m.p.h.
(6)	Cranwell	Reading	125 m.p.h.

Examples 7 (*Chart*)

(A) Find the approximate time taken in each case.

(B) Using the answer from (A) instead of the last column, calculate the actual ground speed.

	From	To	Ground speed
(1)	Shipwash Lt.	Lowestoft	56 knots
(2)	Kentish Knock Lt.	N. Hinder Lt.	66 knots
(3)	Ramsgate	Ostend	70 knots
(4)	Dungeness	Calais	80 m.p.h.
(5)	Colchester	N. Hinder Lt.	52 m.p.h.
(6)	Zeebrugge	Wells	65 m.p.h.

CHAPTER II

THE MEASUREMENT OF DIRECTION

Direction or Bearing

The direction or bearing of a place B from another A, on the surface, is given by the great circle AB, and measured by the angle from some known great circle such as the true meridian at A, to this circle AB*. This angle is measured from North, called 0°, clockwise, from 0° to 360°.

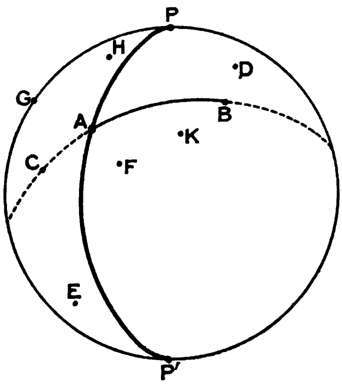


Fig. 4

Thus in Fig. 4 the true bearing of B from A is about 50°, and the true bearing of C from A is about 230°.

These great circles may, for short distances, be taken as horizontal straight lines, and are drawn on the map or chart as such without any practical error, so that any bearing is always measured by the angle between two straight lines.

Suppose that one or both of the places are not on the surface, as in Fig. 5, in which B is a lighthouse, S a seaplane on the sea, and A an aeroplane directly above S.

Then if ST and AT are the horizontal lines towards true north, and SL and AM the horizontal lines passing directly below and above B, the true bearing of B from S is the angle TSL, and the true bearing of B from A is TAM, the two angles being exactly the same.

Examples 8

(1) State, quite roughly, the true bearings from A of the points P, P′, D, E, F, G, H, and K, in Fig. 4.

(2) Estimate roughly the true bearing of the light in Fig. 5, from the points X, Y, Z, on the sea level.

* This angle at A is measured by the angle between the two straight lines at A, drawn to touch the arcs AP and AB.

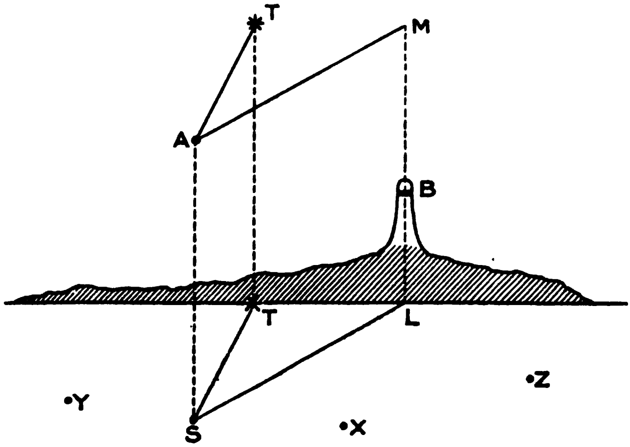


Fig. 5

The bearing or direction of one place from another on a map or chart, is in Air Navigation measured by the angle, reckoned clockwise, from the North point of the meridian to the straight line joining the places.

Note. If the places are a large distance apart, the meridian chosen should be one about midway between them.

For seaplanes working in conjunction with ships, it is frequently necessary to know the method of reckoning directions from N. to E., S. to E., etc.

This connection is shown by Fig. 6.

Thus

N. 35° E. is 35°
S. 35° E. is 145°
S. 35° W. is 215°
N. 35° W. is 325°

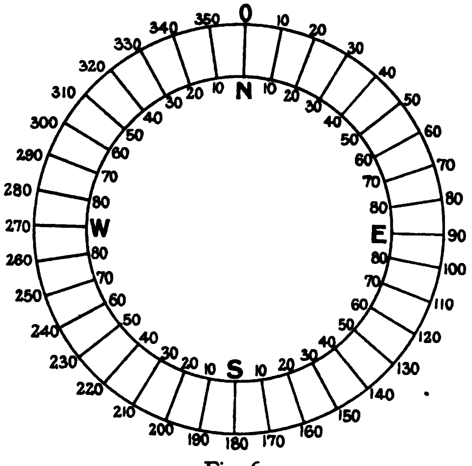


Fig. 6

The Magnetic Meridian

Except in the case of the wind it is seldom necessary either to lay off or measure directions from the true meridians. A much more convenient line of reference is the Magnetic Meridian, which over any small area may be considered to make the same angle with all the true meridians.

The Magnetic Meridian at a place is the line in which a magnetised needle would lie if suspended so as to be horizontal and not influenced by any magnetic substance in the immediate neighbourhood. The angle it makes with the true meridian is called the variation.

Thus on the map provided it will be seen that the Magnetic Meridian is drawn with the North or marked end 15° West of the true North, i.e. the Variation is 15° W. On the chart provided it is seen to be 13° W.

When using a map, one or two magnetic meridians should be ruled in right across it.

Directions measured from the Magnetic Meridian are marked "magnetic" or briefly (mag).

If the ordinary chart, as used by ships, is employed for air work, it will be found useful to rule one or two magnetic meridians across the chart, using the variation stated, after allowing for the change since the date of publication. Thus if the variation shown is 13° 30′ W. in 1917, decreasing 9′ annually, the variation in 1920 would be 13° 30′ − 27′ or 13° W.

Note. In charts specially designed for air work this is unnecessary.

Direction of the Wind

The direction from which the wind is blowing is given as true, but for the convenience of pilots is frequently corrected to magnetic by the meteorological officer. This is easily done as shown in the following examples.

Example 1. The wind is from 60° (true). What is the magnetic direction if the variation is 18° W.?

Draw OT the true meridian (see Fig. 7) and put in OM the magnetic meridian, M being 18° to the West of T. Then if AO is the direction of the wind, the angle TOA is 60° and therefore the magnetic direction is MOA or 60° + 18°, i.e. 78°.

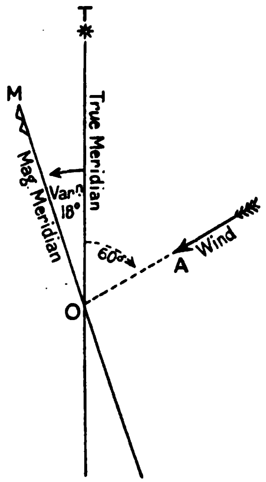


Fig. 7

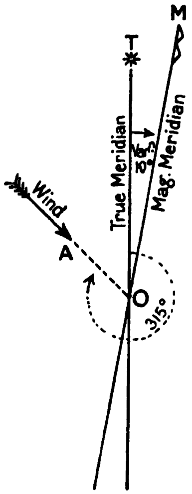


Fig. 8

Example 2. The wind is from 315° (true). What is the magnetic direction if the variation is 10° E.?

In this case M is 10° to the East of T, and the angle MOA is 315° − 10° or 305° (see Fig. 8).

Hence to obtain Magnetic from True, add variation if West and subtract if East.

Note. Bear in mind that it may be necessary to add or subtract 360°, for 5° is the same as 365°, etc.

When the chart or map contains the true and magnetic "roses" as on the one provided, the conversion can be done by putting a straight edge from the centre to the true direction (on the outer circle); the magnetic direction being the corresponding point on the inner circle.

Examples 9

In questions 1 to 6, draw the line to represent the true meridian, put in the magnetic meridian and an arrow to denote the wind, and deduce from the figure the magnetic direction of the wind when it is given as:—

(1) From 105° (true); Var. 12° W.
(2) From 210° (true); Var. 10° E.
(3) From 15° (true); Var. 20° E.
(4) From 0° (true); Var. 8° E.
(5) From 345° (true); Var. 20° W.
(6) From 15° (true); Var. 30° E.
(7) Read off the magnetic directions from the roses on the chart [Var. 13° W.] corresponding to (*a*) from 120° (true); (*b*) from 0° (true); (*c*) from 350° (true).

To Measure a Direction*

Suppose that it is required to find the direction from Cambridge to Bedford, or of some line parallel to this.

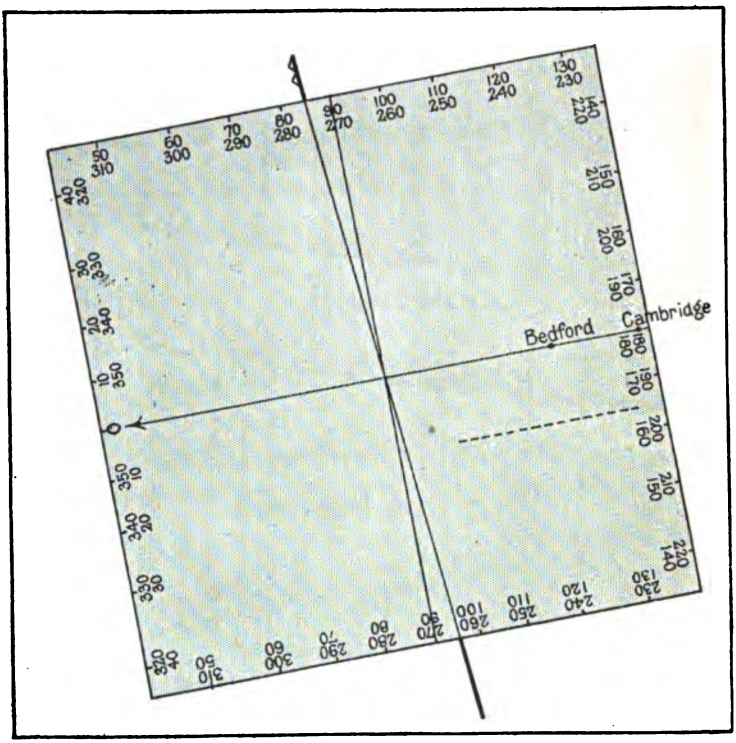


Fig. 9

* Omit if not working with a Douglas Protractor.

Lay the protractor on the map, polished side downwards. Put the centre hole at Cambridge, or on the given line, with the arrow in the direction to be measured.

Slide the protractor along either way until the centre hole is on the magnetic meridian, and the line on the map (i.e. from Cambridge to Bedford) coincides with the arrow line on the protractor or any of the lines on the protractor parallel to the arrow line. (See Fig. 9.)

The direction required is then given by the inner figures where the North or marked end of the magnetic meridian cuts the protractor; in this case it will be found to be 273° (Magnetic).

THE TRACK ANGLE

When flying from one place to another, the direction will be called "the track angle" and marked "true" if measured from a true meridian and "magnetic" if from the magnetic meridian.

It will be found simpler to always use "magnetic."

Examples 10 (*Map*)

Find the track angle, both true and magnetic, and the distance from:—

(1) Oxford to Bedford.
(2) Bedford to Northampton.
(3) Coventry to Cambridge.
(4) Oxford to Cranwell.
(5) Cambridge to Grantham.
(6) Derby to Coventry.
(7) Northampton to Nottingham.
(8) Reading to Greenwich.

Examples 11 (*Chart*)

Find the track angle, both true and magnetic, and the distance from:—

(1) Calais to Smith's Knoll Lt.
(2) Cromer to Steen Bank Lt.
(3) W. Hinder Lt. Vessel to Harwich.
(4) N. Hinder Lt. Vessel to Yarmouth.
(5) Harwich to Zeebrugge.
(6) 52° 55′ N., 3° 4′ E. to Lowestoft.
(7) Varne Lt. Vessel to 52° 45′ N., 2° 30′ E.
(8) Varne Lt. Vessel to Wells.

To lay down a Direction or Bearing on a Map*

Suppose that it is required to lay off 130° (magnetic) from Peterborough. Place the protractor, polished side downwards, with the centre hole on the magnetic meridian, and the edge of the protractor cutting the North or marked end of the magnetic meridian at 130° (inner figures).

Rule a line on the map parallel to the arrow line: move the protractor parallel to itself, i.e. without twisting it, so that an edge passes through Peterborough and the line drawn on the map is seen, by eye, to be parallel to one of the protractor lines, and therefore to the arrow.

From Peterborough draw a line in the direction given by the arrow line on the protractor, this is the direction 130° (magnetic) from Peterborough.

Note. In many cases it is unnecessary to rule the line on the map: thus in the example given, the protractor when set to 130° (mag) can be moved down the magnetic meridian, keeping both the centre hole and the 130° mark on it, until an edge passes through Peterborough.

Examples 12 (*Map*)

Lay down the following directions from the towns named:—

(*The accuracy of the plotting can be tested by the answers.*)

(1) 63° (mag) from Leicester.	(5) 32° (mag) from Bedford.
(2) 120° (mag) from Derby.	(6) 304° (mag) from Greenwich.
(3) 288° (mag) from Cambridge.	(7) 77° (mag) from Oxford.
(4) 257° (mag) from Cambridge.	(8) 187° (mag) from Grantham.

On charts where the magnetic rose is marked from 0° to 360°, an alternative method of laying off a direction is as follows:—

Example. Lay off 220° (mag) from Shipwash Lt.

Put one of the lines on the protractor over both the centre and the 220° mark of the rose, and rule a line with one of the edges which are parallel to this protractor line.

Move the protractor parallel to itself until one of the edges passes through the Shipwash Lt., seeing that the line previously drawn on the chart is parallel to it, and through the Light draw the required line, taking care that this is drawn in the direction from the centre to 220°.

Directions when given true can be similarly laid off from the true rose.

* Omit if not working with a Douglas Protractor.

Examples 13 (*Chart*)

Lay down the following directions from the places named:—

(*The accuracy of the drawing can be tested by the answers.*)

(1) 42° (mag) from Ramsgate.
(2) 133° (mag) from Kentish Knock Lt.
(3) 326° (mag) from N. Hinder Lt.
(4) 355° (mag) from N. Hinder Lt.
(5) 119° (true) from Colchester.
(6) 255° (true) from Dunkerque.
(7) 294° (true) from 52° 38′ N., 3° 0′ E.
(8) 315° (true) from 51° 35′ N., 3° 10′ E.

CHAPTER III

POSITION BY CROSS BEARINGS

When the bearings of two places can be determined, the position of the aircraft can be ascertained as shown in the following example.

It is obvious that there is no need to employ this method when over land in the day time, unless there is a local ground mist below you.

Example. At 11 p.m. Boston bore 55° (mag) and Wisbech bore 135° (mag). Find the position.

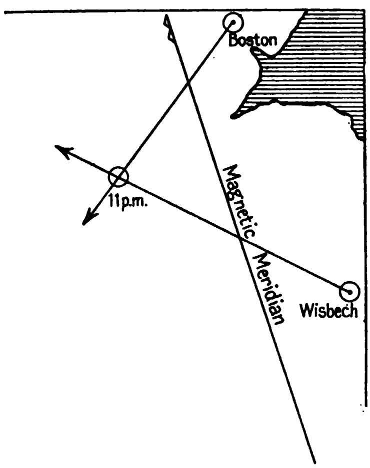


Fig. 10

Since the direction of the line from the aeroplane to Boston is 55° (mag) it follows that the direction from Boston to the aeroplane must be exactly opposite, namely 180° + 55° or 235° (mag); this is sometimes called the "back bearing."

Hence if the direction 235° (mag) is laid off from Boston, the aeroplane must be somewhere on this line.

Similarly it must be somewhere on a line drawn in the direction 180° + 135° or 315° (mag) from Wisbech.

The observed position, sometimes termed the "fix," must therefore be at the intersection of these two lines (see Fig. 10).

Note. It is a good plan to mark a fix by a small circle with the time against it.

Reliability of the Fix

The accuracy of the "fix" depends on the distances and the "angle of cut" of the two lines of bearing: the less the distances and the nearer the angle of cut to 90°, the better the fix.

The object whose bearing is changing most rapidly should be observed last.

The fix is unreliable unless the bearings are practically simultaneous.

Position by "Transit" and a Bearing

If one place A is seen from an aircraft to be in line with another B, it is said to be "in transit," and frequently written A ϕ B, the first named place being the nearer.

This observation therefore gives the information that the aircraft is somewhere on the line joining B and A, and if a bearing of a third place is taken the position can be found.

Note. For a good fix by this method the distance between A and B should be large compared with the distance of the aircraft from A, and the nearer the third place the better.

As in the case of cross bearings, the nearer to 90° that the "angle of cut" of the two lines is, the better the fix.

Examples 14 (*Map*)

Fix the position and give the distance and the desired track angle (mag) to the town named in brackets:—

(1) Bedford bore 311° (mag) and Cambridge bore 49° (mag). (Cambridge.)

(2) Reading bore 220° (mag) and Oxford bore 285° (mag). (Cambridge.)

(3) Derby bore 331° (mag) and Nottingham bore 0° (mag). (Peterborough.)

(4) Peterborough was in line with Wisbech, and Grantham bore 350° (mag). (Cambridge.)

(5) Nottingham in transit with Derby, and Grantham bore 121° (mag). (Leicester.)

(6) Northampton in transit with Bedford, and Coventry bore 312° (mag). (Peterborough.)

Examples 15 (*Chart*)

Fix the position and find the distance and the desired track angle (mag) to the town named in brackets:—

(1) W. Hinder Lt. bore 0° (mag) and Middlekercke Lt. bore 90° (mag). (Dover.)

(2) Steen Bank Lt. bore 108° (mag) and W. Hinder Lt. bore 236° (mag). (Colchester.)

(3) Kentish Knock Lt. bore 278° (mag) and W. Hinder Lt. bore 175° (mag). (Zeebrugge.)

(4) Cross Sands Lt. in transit with Would Lt. Southwold bore 270° (mag). (Harwich.)

(5) W. Hinder Lt. ϕ Middlekercke Lt. Dunkerque bore 180° (mag). (Calais.)

(6) Shipwash Lt. ϕ Orford, and N. Hinder Lt. bore 65° (mag). (Ostend.)

A brief account will now be given of the method of finding magnetic direction by means of the compass.

Note. The elementary magnetism, a knowledge of which is necessary to understand the correction of a compass, and the method of making up a deviation table, will be found in Chapters XIII and XIV.

For Extra Notes

CHAPTER IV

THE MAGNETIC COMPASS

Compasses used in aircraft are of various designs, and only the items common to all will be dealt with.

(1) A magnetised needle, attached to a diameter of a circular "Compass Card" is suspended so as to pivot about its centre and remain horizontal.

If the material in the aircraft caused no disturbing effect on the needle, it would point in the direction of the magnetic meridian at the place. When this disturbing effect has been removed as far as practicable (see Chapter XIV) it points within a few degrees of the magnetic north, the difference, called the "deviation," varying according to the direction of the aircraft, and in most cases not exceeding 5°.

The needle is said to point to the Compass North, and the line in which it lies is called the compass meridian. All directions by compass are measured clockwise from the Compass North.

(2) The card is encased in a "Compass Bowl" which is attached to the aircraft and filled with alcohol and water. The bowl therefore turns with the craft, but the needle only varies its direction to a slight extent.

(3) The edge of the Compass Card is marked from 0° to 360°, the 0° representing that end of the needle which is, very roughly, pointing north.

In most aircraft compasses, the final figure 0 is omitted to avoid crowding the figures, so that if an imaginary line from the centre of the card to an object cuts the card at 3, the compass direction of the object is 30°: similarly a compass direction of 210° will be shown on the card by the mark 21.

(4) The Lubber line, or Lubber's point, gives the direction of the craft's nose; it is a mark on the inside of the compass bowl (which is rigidly attached to the craft).

It should be so placed that a horizontal line joining it to the centre of the card is exactly in the centre "fore and aft' line (i.e. from nose to tail), or else parallel to it (see Fig. 11).

Thus if the needle is pointing as in the figure, and L is the lubber line, the reading of the card at L gives the direction of the nose by compass (called the compass course), and the reading at the point where OA, the horizontal line to an object A, cuts the card will be the compass bearing of A.

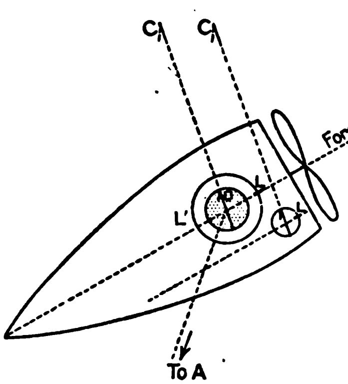


Fig. 11

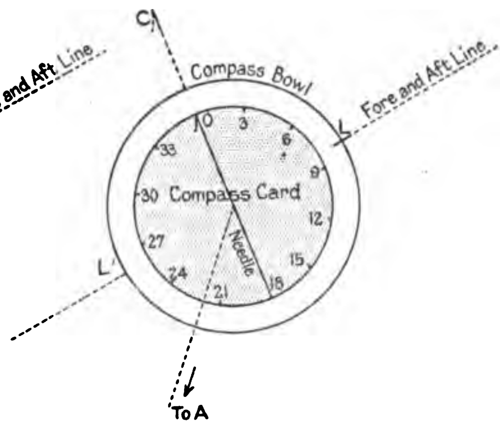


Fig. 12

In Fig. 11 the compass course is about 80°, and the compass bearing of A is about 220°.

The Back Lubber Line

In compasses of the vertical type there is generally also a "back" lubber line marked on the glass, and in the earlier types this is the only one. It corresponds to the point L' shown in Fig. 12.

This presents no difficulty in reading the compass course, as the card is marked differently to allow for it*, but it is

* Thus if the nose is pointing South, the tail would be pointing North, so that the mark on the card at L' would be S.; it is a case of "North being marked South to avoid mistakes."

confusing when altering course, and the best way is to look on it, for the moment, as representing the tail of the machine.

Hence if you want to alter course 20° to the right (or to "starboard"), the *tail* of the machine will go to the left, and therefore the *back* lubber line should move 20° to the left (or to "port").

Courses

Suppose that O is the compass of an aeroplane, FA the horizontal fore and aft line and OM the direction of the magnetic meridian. Then owing to the iron, steel, etc., in the aeroplane the compass needle will set itself in some direction such as OC, the angle MOC being the deviation of the compass for the particular direction in which the aeroplane is pointing.

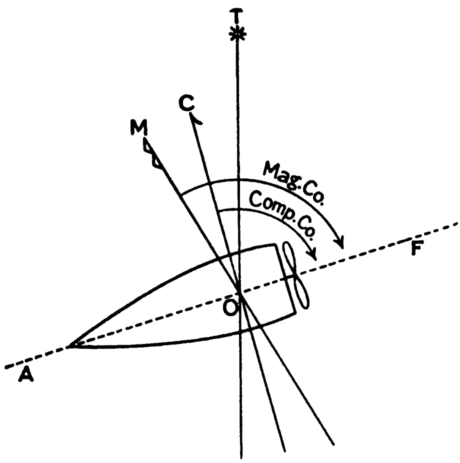


Fig. 13

The angle clockwise from OC to the fore and aft line FA is called the compass course, and the angle MOF is the magnetic course.

The difference of these two is clearly the angle MOC, i.e. the deviation, which in this case is marked E, since C is to the East of M.

To find the Magnetic Course from the Compass Course

This is done by inspection, with sufficient accuracy for practical air navigation, from either of the "Conversion Tables" given on the inside of the front cover.

These are constructed, when on the ground, by comparing the various magnetic directions of the nose with the corresponding directions by compass (i.e. readings of the lubber line), as described in Chapter XIV.

Thus if the magnetic course is 120°, using Table (1) and following up the cross line from 120° in the left-hand column, it is seen that this compass will mark between 11 and 12, i.e. the compass course is 116° or 117°.

Note. For the present no attention need be paid to the figures in the deviation column.

The same result follows from the use of the circular diagram, where the inside figures represent magnetic courses, with the final 0 omitted; thus for 120° (mag) look at 12, and follow the cross line from it outwards.

Similarly to find the magnetic course corresponding to the compass mark 22, look at the compass mark 22 in Table (1) or 220 in Table (2), and imagine a line drawn from this point slanting similarly to those at each side of it: this shows a magnetic course of 226° or 227°.

Note. These tables will be used in all examples in the book.

Examples 16

(1) Read off (roughly) the compass courses corresponding to the magnetic courses:—

0°; 210°; 250°; 340°; 70°; 110°; 280°; 235°; 255°; 351°; 155°; 243°.

(2) Read off the magnetic courses corresponding to the compass marks:—

0; 20; 2; 30; 3; 34; 22; 4; 35; 24; 11; 23.

(3) Read off the magnetic courses corresponding to the compass courses:—

182°; 225°; 173°; 71°; 62°; 345°; 5°; 305°; 118°; 154°; 245°; 78°.

For Extra Notes

CHAPTER V

TAKING A BEARING

To take the Bearing of an Object by the Vertical Compass

A convenient method of finding the magnetic bearing of an object when no great accuracy is necessary is as follows:—

Let Fig. 14 represent the fuselage of an aeroplane, P the position of the pilot's head, O the compass, and FOP the central fore and aft line.

Then if the magnetic meridian be as shown, it is clear that the angle MPF is the magnetic course.

Put marks B, C, ... on the fuselage so that the angle FPB is 30°, FPC is 60°, etc., and number these marks 3, 6, 9, ... 33.

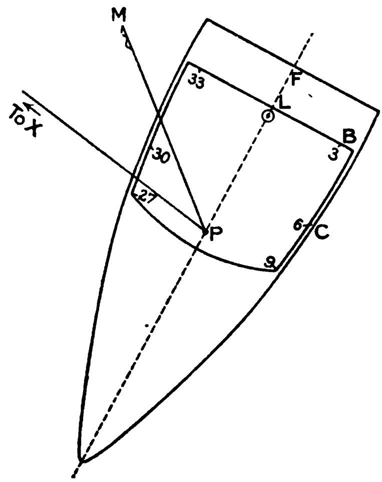


Fig. 14

If an object is seen to be in the direction PX, the angle FPX, measured clockwise from the nose, is about 280°, and if the magnetic course MPF (in this case about 50°) be added, the clockwise angle MPX is obtained.

Thus the magnetic bearing of X is 280° + 50° or 330°.

This angle FPX will be called the "angle from nose."

Note 1. For this rough method, the compass course can be regarded as the magnetic course.

Note 2. If the sum of the two angles exceeds 360°, subtract 360°.

Note 3. When the angle from nose is 90°, the object is said to be on the starboard beam.

When the angle from nose is 270°, the object is said to be on the port beam. The marks from 12 to 24 are clearly of little use to the pilot.

Example. You are steering by the compass mark 30, and an object is seen in the direction of the mark 27 on the fuselage. What is roughly its magnetic bearing?

Mag bearing = Mag Course + Angle from nose
= 300° + 270°
= 570° (or, subtracting 360°)
= 210°.

Examples 17

Find the rough magnetic bearing in the following cases:—

(1) Compass Course 45°; angle from nose 30°.
(2) Compass Course 200°; angle from nose 240°.
(3) Compass mark steered by is 24; angle from nose is 50°.
(4) Compass mark steered by is 33; angle from nose is 300°.
(5) Compass mark steered by is 3; object is in the direction of the mark 33 on fuselage.
(6) Compass mark steered by is 30; object is in the direction of the mark 27 on fuselage.

The Bearing Plate

The Bearing Plate affords a more accurate means of finding the magnetic bearing of an object.

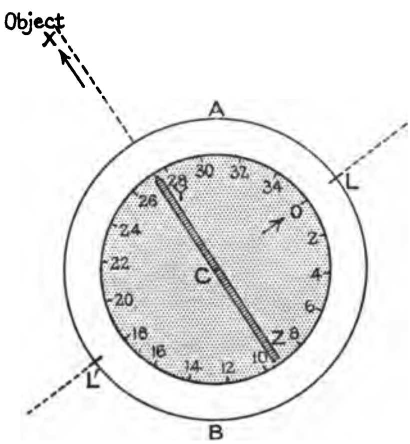


Fig. 15
Bearing Plate

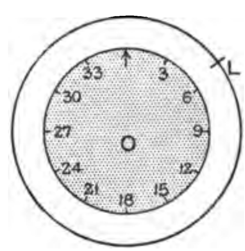


Fig. 16
Compass

This plate is placed in a position from which a clear all-round view can be obtained and consists of a fixed flat outer ring ALB (Fig. 15) whose centre is C.

The mark at L corresponds to the lubber line L on the compass bowl shown in Fig. 16, CL being fixed parallel to the fore and aft line. The inner disc is moveable and marked to show degrees.

For the purpose of taking bearings it is simpler to keep the zero mark always at L.

The centre bar is pivoted at C and carries a sight vane at Y to enable the pointer at Y to be set to the direction of the object.

CL being parallel to the central fore and aft line, the "angle from nose" of an object X can be read off from the inner disc.

As before, the magnetic bearing is obtained by adding this angle to the magnetic course, which is obtained from the compass course by means of the Conversion Table.

Thus if the compass course is 50° and the angle from nose to X is 277°, we have, from the Conversion Table, compass course 50° = mag co. 46°.

Therefore Magnetic Bearing of X = 277° + 46° = 323°.

Note. An alternative method of finding the bearing is to regard the inner disc as a "dummy compass" and set the compass course to L; the reading of the pointer Y on the inner disc will then be the compass bearing of the object, and must be corrected for deviation in the manner shown further on.

The great drawback to this method is that the disc has to be reset after any alteration of course if a bearing is required.

Bearing by Horizontal Prismatic Compass

When the compass in use is of the horizontal type, with a *moveable* prismatic attachment, the compass bearing of any object is easily found by turning the pointer and prism to the object, the reading being found by looking in the prism.

To reduce this compass bearing to magnetic, the deviation must be applied, and it must always be borne in mind that this depends on the compass *course* and not on the compass *bearing* of the object.

Example 1. The Compass Course was 40°, and an object X bore by compass 140°; find the magnetic bearing.

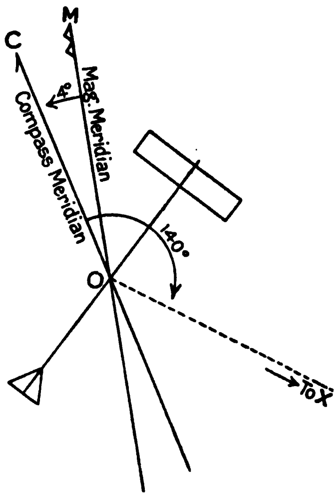


Fig. 17

If OM in Fig. 17 is the magnetic meridian, then the Conversion Table shows that the compass course of 40° corresponds to the magnetic course of 36°, so that C is 4° West of M, or the deviation is 4° W.

Hence Compass Bearing	COX =	140°,
Deviation	MOC =	4° W.
∴ Magnetic Bearing	MOX =	136°

Note. If the mistake had been made of taking the deviation for 140° (the compass bearing), namely 5° E., the magnetic bearing would come to 145°, an error of 9°.

Conversion Table (1) enables the deviation for any magnetic or compass course to be taken out at sight.

Example 2. Compass Course 220°; object bore 275° by compass. Find the magnetic bearing.

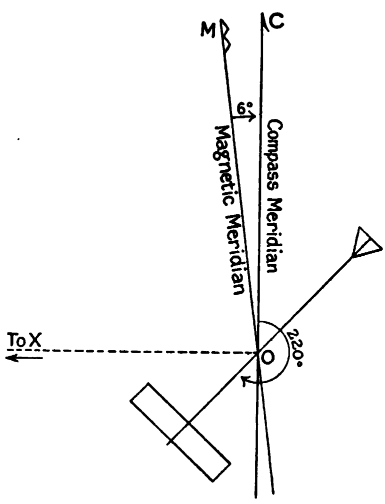


Fig. 18

From the Conversion Table, the deviation for 220° is 6° E.

Compass Bearing	COX =	275°
Deviation	MOC =	6° E.
∴ Magnetic Bearing	MOX =	281°

Note. If the deviation had, by mistake, been taken out for 275°, it would be 1° W., and the magnetic bearing found would be 274°, an error of 7°.

It will be seen from these two examples that if the deviation is East the compass bearing is always less than the magnetic bearing, and if the deviation is West, the compass bearing is greater than the magnetic bearing.

"**Deviation East, Compass Least**" will be found a useful and easy jingle to remember.

Examples 18

(1) Find the magnetic bearings in the following cases:—

(*a*) Compass Bearing 20°; Compass Course 220°.
(*b*) Compass Bearing 220°; Compass Course 30°.
(*c*) Compass Bearing N.; Compass Course 150°.
(*d*) Compass Bearing 355°; Compass Course 230°.
(*e*) Compass Bearing 2°; Compass Course 50°.
(*f*) Compass Bearing N.; Compass Course W.

(2) (*Map.*) Fix the position of the aeroplane, and give the distance and desired track angle (mag) to the place mentioned in brackets:—

(*a*) Compass Course 215°; Bedford bore by compass 77°; and at the same time Northampton bore by compass 340°. (Oxford.)
(*b*) Compass Course 145°; Derby 336° (comp.) and Nottingham 55° (comp.). (Cambridge.)
(*c*) Compass Course S. (comp.); Peterborough was in line with Wisbech, and Cambridge bore 147° (comp.). (Kingston.)

(3) (*Chart.*) Give the latitude and longitude of the seaplane, the desired track angle (mag), and the distance from it to the place named in brackets:—

(*a*) Course 145° (comp.); Kentish Knock Lt. bore 184° (comp.); Shipwash Lt. bore 85° (comp.). (Dungeness.)
(*b*) Course 210° (comp.); W. Hinder Lt. bore 356° (comp.), and Middlekercke Lt. bore 85° (comp.). (Dunkerque.)
(*c*) Course 50° (comp.); Varne Lt. ϕ Dungeness. Dover bore N. (comp.). (W. Hinder Lt.)

Also Examples **A_1**, **A_2**, Appendix.

Checking the Deviation

It is very important to check the correctness of the Conversion Table, or the deviation, whenever possible, as it is liable to alter. A simple and convenient method is to take the bearing of two places by compass when they are in line, and compare it with the magnetic direction of the line joining the two places on the map or chart.

Example. Bedford was observed to be in line with Northampton and to bear 300° by compass. (Compass Course was 215°.) Find the deviation.

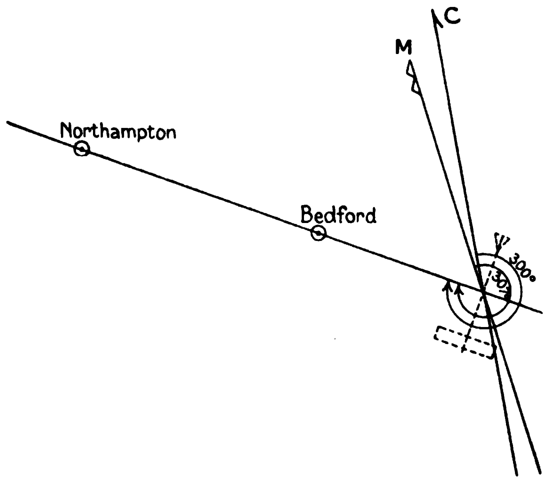


Fig. 19

From the map it is found that the magnetic direction of the line from Bedford to Northampton is 307°.

Hence Mag. Bearing	=	307°
Comp. Bearing	=	300°
∴ Deviation [for comp. co. 215°]	=	7° E.

The deviation is seen to be E. either from a figure or by the rule "Compass least, Deviation East."

This result practically agrees with the tabulated deviation of 6° E. for the compass course in question.

Examples 19 (*Map*)

Find the deviation and see whether it has altered appreciably:—

(1) Grantham was in line with Cranwell, and bearing 49° by compass. Compass Course 150°.

(2) Peterborough in transit with Wisbech bearing 87° (comp.). Course W. (comp.).

(3) Nottingham ϕ Derby bearing 275° (comp.). Course 340° (comp.).

(4) Oxford ϕ Reading bearing 157° (comp.). Course 215° (comp.).

Examples 20 (*Chart*)

Find the deviation and see whether it has altered appreciably:—

(1) Shipwash Lt. in line with Kentish Knock Lt., bearing 25° (comp.). Course 50° (comp.).

(2) Would Lt. ϕ Cross Sands Lt., bearing by compass 167°. Course 300° (comp.).

(3) Middlekercke Lt. ϕ W. Hinder Lt., bearing 311° (comp.). Course 200° (comp.).

(4) Smith's Knoll Lt. in transit with Would Lt., bearing 283° (comp.). Course N.E. (comp.).

For Extra Notes

CHAPTER VI

THE EFFECT OF WIND

Air speed is the speed in still air, or if the air is in motion, the speed through *this* air. It is found by the "air speed indicator."

Note. As the reading of the "A.S.I." depends on the density of the air, as well as on the engines, a correction for height should be applied to the reading (see p. 83).

Thus if the *air* speed (corrected for height) is 100 m.p.h., and the machine is flying directly with a wind of 30 m.p.h., the *ground* speed will be 100 + 30, or 130 m.p.h.: if flying directly against this wind, the ground speed will be 70 m.p.h.

The speed of the wind is generally given in miles per hour, but for sea work is sometimes given in knots.

The direction of the wind may be given either "true" or "magnetic." In practice it is generally more convenient to deal with magnetic, any small change in the variation being of no consequence in this respect.

Angular Drift

If an aircraft leaves X (see Fig. 20), and steers the magnetic course MXY, whilst from observation of ground objects she is found to be passing over the line XZ, then the angle YXZ will be called the angular drift.

The angular drift is therefore the angle between the fore and aft line and the track.

Note. It should be noticed that the aeroplane always points in a direction parallel to XY.

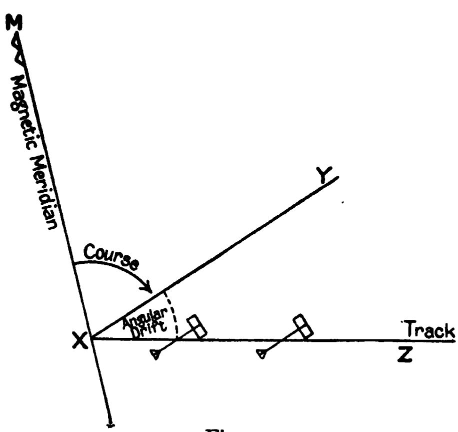


Fig. 20

The no drift (N.D.) position is the place in which the aircraft would be if there were no wind: it is clearly on the line XY, and is found from the course steered and the air speed.

The actual position is on the line XZ.

To find the Speed and Direction of the Wind

Method (i). [By trial]

In the case of an airship, it is possible to find the direction and speed of the wind by altering course and speed until it is found that the ship is stationary over some ground object, when your direction and indicated speed will be that of the wind.

This method is not however practicable in the case of an aeroplane or seaplane, until hovering is possible.

Note. A streamer, attached to a machine in motion, will always blow out in the fore and aft line, unless side slipping is taking place.

Method (ii). [By plotting]

If the N.D. and the actual positions after any interval are known, the direction and speed of the wind can be at once found.

Example. (*Map.*) An aeroplane is over Leicester at 8.40 a.m., steering 85° (comp.), air speed 80 m.p.h., and at 9 a.m. she is over Grantham. Find the speed and direction of the wind.

From 8.40 a.m. to 9 a.m. is 20 minutes; in this time her engines will have taken her $\frac{80}{3}$ or 27 miles in still air.

Lay off 85° (comp.), i.e. 84° (mag), from Leicester (see Fig. 21), and measure off 27 miles along it.

This is the N.D. position at 9 a.m. and is conveniently denoted by a dotted circle. But at 9 a.m. she is observed to be over Grantham.

Therefore in 20 minutes the effect of the wind is to have moved her from the N.D. position to Grantham.

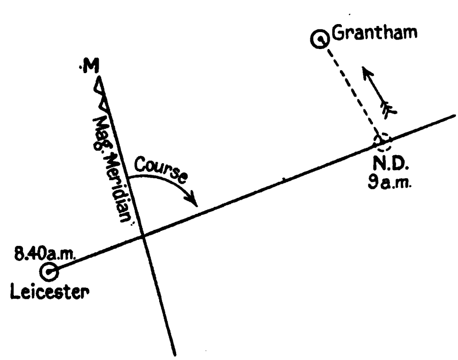


Fig. 21

By measurement N.D. to Grantham is 10 miles.

The speed of the wind is therefore $10 \times \frac{60}{20}$ or 30 m.p.h.

The direction of the wind being always given as that of the point it is blowing *from*, will be the direction of the N.D. position from Grantham, i.e. 166° (mag).

Method (iii). [By estimation from the surface wind]

When no ground objects are available to determine the actual ground speed, the wind has to be estimated from the conditions on the surface as described on pp. 87, 88.

The speed and direction of the wind found from any of these methods cannot be relied on to remain entirely unaltered for a further flight, and must be regarded simply as an estimate.

Examples 21 (*Map*)

Mark the N.D. position at the time of the second observation, and estimate the speed of the wind (in m.p.h.), and its direction (mag):—

(1) At 5.45 p.m. an aeroplane was over Reading, steering N. by compass, air speed 85 m.p.h.; and at 6.5 p.m. it was over Oxford.

(2) An aeroplane was over Cambridge, the compass course being W.; air speed 90 m.p.h.; 12 minutes later it was over Bedford.

(3) At 7.50 a.m. an aeroplane was over Coventry, course 64° (comp.); air speed 120 m.p.h. At 7.58 a.m. it was over Leicester.

(4) At 10.21 a.m. an aeroplane, steering 215° by compass, passed over Peterborough, her air speed being 90 m.p.h.; at 10.39 a.m. she passed over Northampton.

Also Examples B_1, Appendix.

Examples 22 (*Chart*)

Mark the N.D. position at the time of the second observation, and estimate the speed of the wind (in knots) and its direction (mag):—

(1) A seaplane is over the Cross Sands Lt., her compass course being 56° and air speed 65 knots; 20 minutes later she is over Smith's Knoll Lt.

(2) A seaplane is over the N. Hinder Lt., and 27 minutes later is over Shipwash Lt. The compass course was 264°, air speed 60 knots.

(3) At 9.10 a.m. an airship was over Southwold, steering 187° (comp.); air speed 45 knots. At 9.43 a.m. she was over the Shipwash Lt.

(4) A seaplane is flying 76° by compass; air speed 70 knots, and passes over Calais 17 minutes after being over the Varne Lt.

Also Examples B_2, Appendix.

CHAPTER VII

THE ESTIMATED POSITION

The estimated track is the line over which it is estimated that the craft has flown, and is found from the course steered, the air speed, and the estimated wind.

The estimated track angle is the angle, reckoned clockwise, from North to the estimated track.

The estimated ground speed is the ground speed found from the course steered, the air speed, and the estimated wind.

The estimated angular drift is the angle between the fore and aft line and the estimated track.

The estimated position is that obtained from the estimated track, and the estimated ground speed.

Example. At 10 p.m. an aeroplane is over Reading: course 35° (mag); air speed 65 m.p.h.; the wind is estimated to be from 60° (true) at 25 m.p.h. Find the estimated ground speed and mark the estimated position at 10.45 p.m.

From R (Reading), lay off 35° (mag) 65 miles, this will be the N.D. position (see Fig. 22) at 11 p.m.

From the N.D. position, lay off the distance the wind has set her in one hour, 25 miles. Call this point C.

Then at the end of one hour, if the wind and air speed have been estimated correctly, the aeroplane will be at C, and will have travelled along the line RC, the estimated track.

The estimated ground speed is therefore given by RC, and is 49 m.p.h.

The estimated angular drift is 19°.

The estimated track angle is 7° (mag).

Now in ¾ hr. the plane has gone ¾ × 49, or 36 miles from Reading along the estimated track RC. This gives the estimated position at 10.45 p.m.

Note. The student should mark the N.D. position after ¼ hr. and ½ hr., allow the amount for the wind for these times, and satisfy himself that the aeroplane will *always* be on the line RC, though she is always pointing parallel to a line drawn from Reading to the N.D. position.

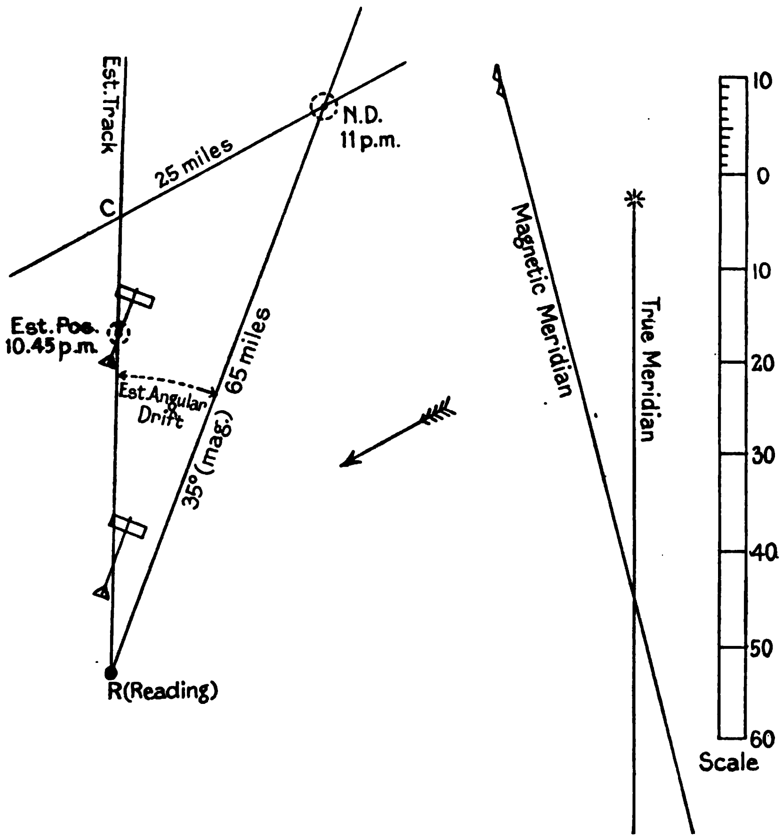


Fig. 22

In practice, it is more convenient to lay down the distances for half an hour, remembering that the resulting value of RC must then be doubled to obtain the ground speed.

Examples 23 (*Map*)

Mark the N.D. position at the end of half an hour and find the estimated speed. Mark the estimated position at the time given in the last column, and find the distance asked for:—

	An aeroplane leaves	Course	Estimated wind	Air speed	Find the distance
(1)	Oxford at 11 p.m.	30° (mag)	from 15° (true); 20 m.p.h.	80 m.p.h.	at 11.30 p.m. from Northampton
(2)	Boston at 1 a.m.	220° (comp.)	from 325° (true); 30 m.p.h.	95 m.p.h.	at 1.45 a.m. from Reading
(3)	Cambridge at 10.45 p.m.	330° (comp.)	from 140° (true); 25 m.p.h.	100 m.p.h.	at 11 p.m. from Peterborough
(4)	Reading at 11 p.m.	35° (comp.)	from 30° (mag); 15 m.p.h.	65 m.p.h.	at 0.30 a.m. from Peterborough

Also Examples C_1, Appendix.

Examples 24 (*Chart*)

Mark the N.D. position at the end of half an hour, and find the estimated ground speed:—

(1) A seaplane leaves Southwold at 4 p.m.; air speed 65 knots; course 80° (mag); estimated wind from N. (mag) at 20 knots. Give the latitude and longitude at 4.30 p.m.

(2) A seaplane leaves Ramsgate at 10.30 a.m.; course 120° (comp.); air speed 80 knots; estimated wind from 60° (true) at 30 knots. Give the latitude and longitude at 11.15 a.m.

(3) A seaplane was over Steen Bank Lt. at 2 p.m.; course 270° (comp.); air speed 70 knots; estimated wind from 260° (mag) at 15 knots. Give the latitude and longitude at 2.40 p.m.

(4) An airship was over W. Hinder Lt. at 11.45 p.m.; air speed 45 knots; course 340° (mag); estimated wind from 150° (mag) at 15 knots. Give the latitude and longitude at 1.30 a.m.

Also Examples C_2, Appendix.

For Extra Notes

CHAPTER VIII

TO FIND THE COURSE, ALLOWING FOR WIND

Given the desired Track, to find the Course to Steer, allowing for Wind

Method (i). [By trial]

Suppose that an aeroplane at O, on the ground, wishes to fly in the direction 50° (mag). (See Fig. 23.)

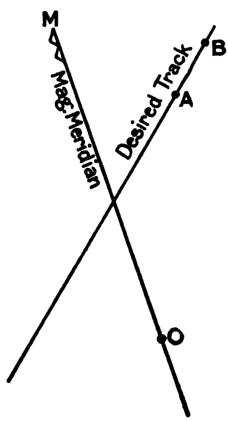


Fig. 23

Place two objects A and B, such as two flares, at some known distance apart, B being 50° (mag) from A. After climbing to the height at which it is proposed to fly, keep altering the course until it is found that A and B are kept in line or "transit."

The compass course is then noted, and the ground speed, on this course, obtained from the time it takes to pass from A to B.

Method (ii). [By plotting]

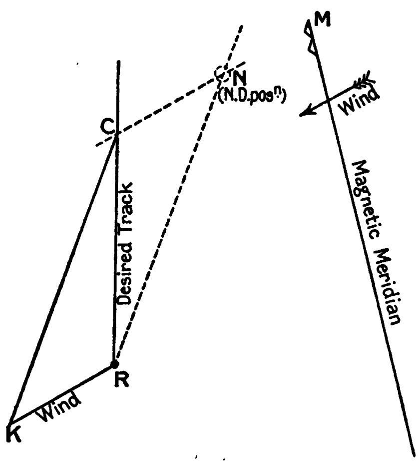


Fig. 24

In the example on p. 36, it has been seen that if the aeroplane steers the given course 35° (mag) (see Fig. 24), and the wind is from 60° (true), she will proceed along RC. It follows therefore that if she wishes to proceed along RC allowing for this given wind, she must steer the course given by R to N.

Now if RK be drawn parallel to CN, and CK parallel to RN, then

RK=CN and CK = RN, and KC is parallel to RN and therefore gives the course required.

Hence the construction is:—

(1) Lay off RK from your position, equal to the amount the wind sets you in an hour.

(2) With K as centre and air speed as radius, describe an arc cutting the desired track in C.

The direction of KC gives the course required.

The estimated ground speed is RC. The estimated angular drift is the angle RCK, since $\angle$ RCK = $\angle$ CRN.

Note. In practice it is easier to take the distances for half an hour.

Example. The air speed is 80 m.p.h. and the estimated wind is from 120° (true) at 25 m.p.h. Find the compass course to set from Greenwich to Peterborough, and the time taken; also the estimated position 20 minutes after passing over Greenwich.

From G, in Fig. 25, lay off GK the distance the wind will set you in half an hour, namely $12\frac{1}{2}$ miles, taking care to lay off the direction of the wind from the true meridian.

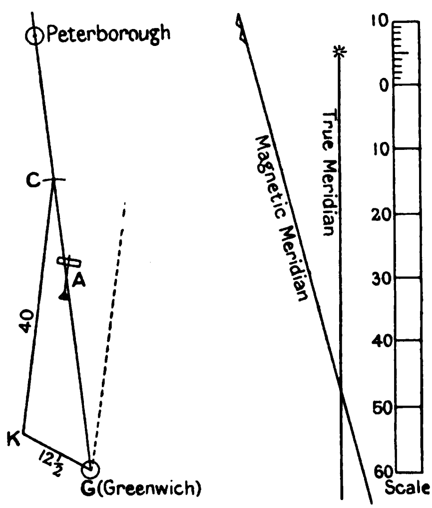


Fig. 25

In half an hour the engines will take you 40 miles, so with K as centre and 40 miles as radius, draw an arc cutting GP in C.

The direction of KC gives the course to steer, and will be found to be 22° (mag).

The compass course is therefore 24°.

GC, by measurement, is 46 miles, and the estimated ground speed is therefore 2 × 46 or 92 m.p.h.

GP is 75 miles, and the time taken will be $\frac{75}{92}$ hrs. or 49 minutes.

The aeroplane is proceeding "crab fashion" along GP at 92 m.p.h., and 20 minutes after leaving Greenwich will therefore be at A.

The angular drift, being the angle between the desired track and the fore and aft line, is the angle KCG, which is 14°.

Note. In this and in all other examples in the book, the "time taken" does not include the time required to climb to the required height.

This varies according to the machine, and must be allowed for if starting from the ground instead of from above the place.

Examples 25 (*Map*)

Find the compass course to steer and the time taken:—

	From	To	Estimated wind	Air speed
(1)	Oxford	Bedford	from 69° (mag) 20 m.p.h.	70 m.p.h.
(2)	Reading	Cambridge	from 232° (mag) 15 m.p.h.	65 m.p.h.
(3)	Cranwell	Northampton	from 120° (true) 25 m.p.h.	80 m.p.h.
(4)	Cambridge	Coventry	from 30° (true) 20 m.p.h.	75 m.p.h.
(5)	Derby	Wisbech	from 60° (true) 35 m.p.h.	100 m.p.h.

Also Examples D_1, Appendix.

Examples 26 (*Chart*)

Find the compass course to steer and the time taken:—

	From	To	Estimated wind	Air speed
(1)	Wells	Smith's Knoll Lt.	from 250° (mag) 15 knots	65 knots
(2)	Cromer	N. Hinder Lt.	from 210° (mag) 20 knots	55 knots
(3)	Zeebrugge	Yarmouth	from 35° (mag) 30 knots	70 knots
(4)	W. Hinder Lt.	Varne Lt.	from 200° (mag) 25 knots	60 knots
(5)	Harwich	Dunkerque	from 135° (true) 20 m.p.h.	90 m.p.h.

Also Examples D_2, Appendix.

Correction of Course for Wrong Estimate of Wind

Since the wind is liable to change, it is very important to determine from time to time whether the desired direction is being maintained, and, if not, to make the necessary alteration in the course.

For this purpose the bearing plate is cut away round the centre and the centre arm is fitted with horizontal wires. Such an instrument is called a "drift corrector."

In Figs. 26 and 27 let L be the arrow on the outer rim, indicating the lubber line, or direction of the nose; then CL will represent the fore and aft line (or the N.D. track).

The angular drift is the angle between the desired track and the fore and aft line, and it is evident that the desired track is always on that side of the fore and aft line which is away from the wind.

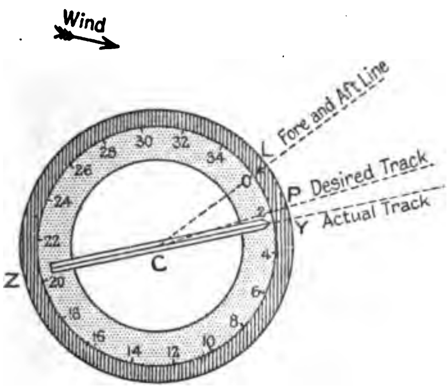


Fig. 26

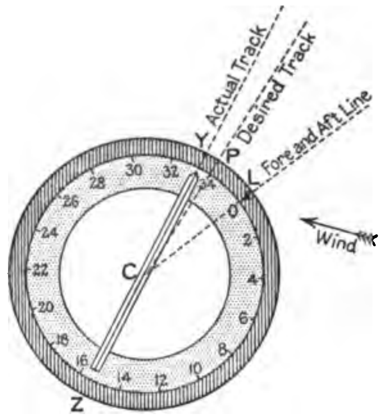


Fig. 27

Suppose that the course has been previously worked out allowing for the estimated wind, and the estimated angular drift has been found to be 20°.

Then if the zero mark on the inner moveable disc is set to the lubber line, the desired track must be 20° from the zero; i.e. the angle LCP is 20°, and if the wind has been correctly estimated, ground objects directly below will appear to be passing along PC.

Turn the central arm YZ until objects appear to be passing along the horizontal wires on it, and suppose it to be then in the position shown in the figure.

Then the angle LCY is the observed angular drift.

Suppose that, in these figures, from L to Y is 25°: then for practical purposes the error in the course is 25°–20°, or 5°.

It will be seen from the figures that if the actual angular drift is larger than the estimated, the course must be altered towards the wind: if less than the estimated, away from the wind.

Note. When the course is again checked, the angular drift last obtained is taken as the "estimated."

Examples $\mathbf{E_1}$, $\mathbf{E_2}$, Appendix.

For Extra Notes

CHAPTER IX

JOINING UP WITH A SQUADRON

Joining up with a Squadron, or Intercepting Hostile Aircraft

Case (i). *When the air speed and course are known.*

Example. A squadron is reported to bear 30° (mag), distant 42 miles, and to be steering 100° (mag); air speed 60 m.p.h. Your own air speed is 80 m.p.h. Find your course to join up and the time taken.

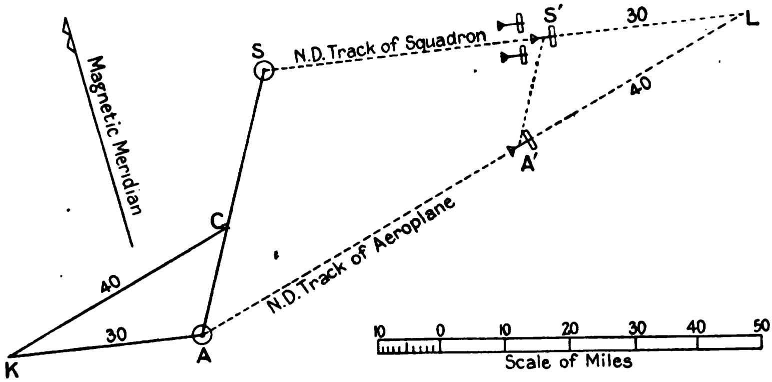


Fig. 28

In Fig. 28, let A be the position of the aeroplane, and S that of the squadron.

From A set off AK in exactly the opposite direction to the course of the squadron, and equal to the distance their engines alone will take them in, say, half an hour, namely 30 miles.

With centre K and radius the distance your own engines will take you in this time, namely 40 miles, cut in the point C.

The direction KC gives the course required, namely 75° (mag).

The "speed of approach," i.e. the rate at which A is decreasing her distance from S, is 2 × AC, or 36 m.p.h.

The time taken to join is $\frac{\text{AS}}{\text{speed of approach}}$ or $\frac{42}{36}$ hrs., i.e. 1 h. 10 m.

Proof

Firstly, disregard the actual wind.

Imagine that a gale is blowing dead against the squadron, i.e. from 100° (mag), and the speed of this gale is the same as the air speed of the squadron.

Then S will be stationary as regards the ground, but your own aeroplane will be subject to this gale, and the problem is therefore to find the course from A to the stationary point S, allowing for a gale of 60 m.p.h. from 100° (mag).

The usual construction as given above is therefore all that is required.

Now the effect of any actual wind, as long as it is the same for all the machines, is simply to move the mass of air, represented by the paper containing the figure, bodily in the direction of the wind, and will not affect the course to be steered, though the *actual* tracks will differ from the N.D. tracks shown in Fig. 28 by dotted lines: the actual position of joining up can be found by laying off from L, the distance the wind has set you in the time.

Note. A′ and S′ show the N.D. positions of the aeroplane and the squadron half an hour before joining.

Examples $\mathbf{F_1}$, $\mathbf{F_2}$, Appendix.

Principle of Constant Bearing

The bearing of the squadron, or of the enemy, is given by the direction AS, and remains unaltered if you are steering the correct course to intercept S.

Hence if you alter course at intervals until you are on one which keeps the bearing constant, it is known that by continuing on it you will intercept S, unless S alters course or speed.

In finding the course to intercept an *enemy* aircraft, it is unlikely that his air speed and course are given, and even if they were, his course is probably being continually altered: but the principle just stated, of altering your own course until you find his bearing is remaining unaltered, always holds, and is of great use in practice.

In certain cases, when the enemy's objective can be assumed, his actual track and ground speed can be ascertained from the times of passing over certain places; the course to intercept him can then be found as follows.

Case (ii). *When the ground speed and observed track of the enemy are given.*

Example. The observed track angle of an enemy airship is 140° (mag) and his ground speed 44 m.p.h. The wind is from N. (mag) at 20 m.p.h. If the enemy bears 20° (mag) distant 38 miles from you, find the course and time taken to intercept him, your own air speed being 70 m.p.h.

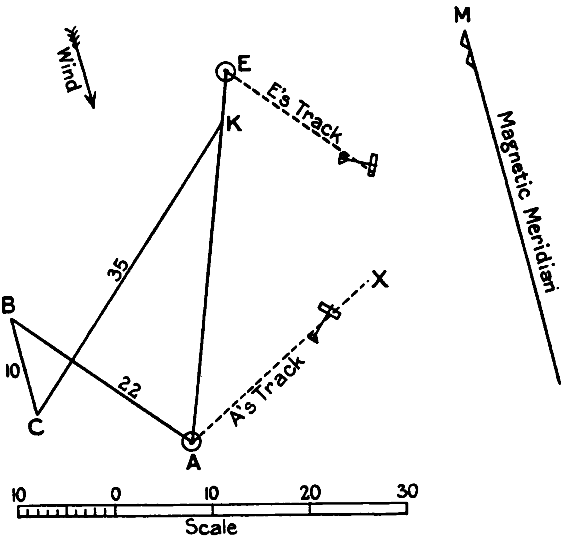


Fig. 29

In Fig. 29, let A be your position and E the enemy.

From A lay off AB parallel to E's track *reversed*, and mark off AB = actual distance E covers in half an hour (22 miles).

From B lay off BC with the wind, and equal to the amount the wind sets you in half an hour (10 miles).

With C as centre and the distance your engines alone take you in half an hour (35 miles) cut in CK.

Then the direction of CK gives the course, 47° (mag).

Also AK by measurement is $32\frac{1}{2}$ miles.

Therefore the rate of approach is 65 m.p.h., and the time taken to intercept E is $\frac{\text{distance AE}}{65} = \frac{38}{65}$ hrs. or 35 mins.

Note 1. A's ground speed is 2 × BK, and A's actual track is AX, parallel to BK.

Note 2. E's air speed is 2 × CA (or 31 m.p.h.), and the direction of CA (116° mag) is E's course.

The method also applies to the case when E is a ship which is steering a given course at a known speed.

Proof

Suppose in Fig. 30 that EZ is E's observed track.
EY = distance covered by E in one hour.
AZ is A's observed track.
AX = distance covered by A in one hour.

Then by the principle stated on p. 47, since A is intercepting E, the bearing of E from A is always the same, i.e. XY is parallel to AE.

Draw XK and AB parallel to EZ, and draw KB parallel to AX.

Then AB = KX = EY = distance covered by E in one hour and KB = AX = distance covered by A in one hour.

If therefore BC be drawn to represent the distance A is set by the wind in one hour it follows that CK must be the distance the engines alone will carry A in one hour, and the direction of CK gives the course to steer.

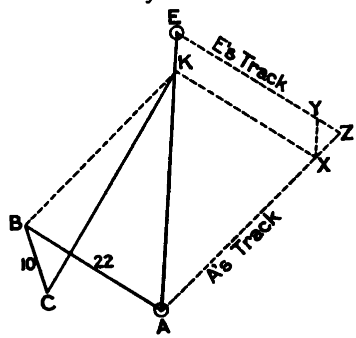


Fig. 30

The point K can therefore be found by laying off AB and BC, and then cutting in CK.

AK gives the rate at which A is approaching E.

Examples G_1, G_2, Appendix.

CHAPTER X

SCOUTING RANGE OR "RADIUS OF ACTION"

Case (i). *Returning to same base.*

When an aircraft has to scout in a given direction and return to her base in a given number of hours, the time when she should turn is found as follows:—

Multiply the ground speed home by the given number of hours, and divide by the sum of the ground speeds out and home.

Proof. Let n be the given number of hours,
T the time to turn, then $n - T$ is the time home,
V the ground speed out,
V′ the ground speed home.

Then on the outward flight, the aircraft does $V \times T$ miles,
on the homeward flight, the aircraft does $V' \times (n - T)$ miles.

Therefore
$$V \times T = V' \times (n - T) = V'n - V'T.$$

Therefore
$$VT + V'T = V'n,$$
$$T(V + V') = V'n,$$

or
$$T = \frac{V' \times n}{V + V'} \text{ hours.}$$

The "scouting range" (i.e. the farthest distance she can go from her base) = ground speed out × T.

Example 1. An aeroplane is ordered to scout in the direction 70° (mag) and return to her starting point in two hours. Her air speed is 80 m.p.h. and the wind is 20 m.p.h. from 70° (mag). Find the time to turn and the scouting range.

In this case the wind is dead against her on the outward flight so that the ground speed out is 80 − 20 or 60 m.p.h.

On the return the wind is directly behind her, and the ground speed home is 80 + 20 or 100 m.p.h.

Hence the time to turn is $\frac{2 \times 100}{60 + 100}$ hrs. or 1 hr. 15 mins.

The scouting range is the distance in this time at 60 m.p.h., which is 75 miles.

Example 2. An aeroplane is ordered to scout in the direction 70° (mag) and return to her starting point in two hours. Her air speed is 80 m.p.h. and the wind is 20 m.p.h. from 140° (mag). Find the time to turn and the scouting range.

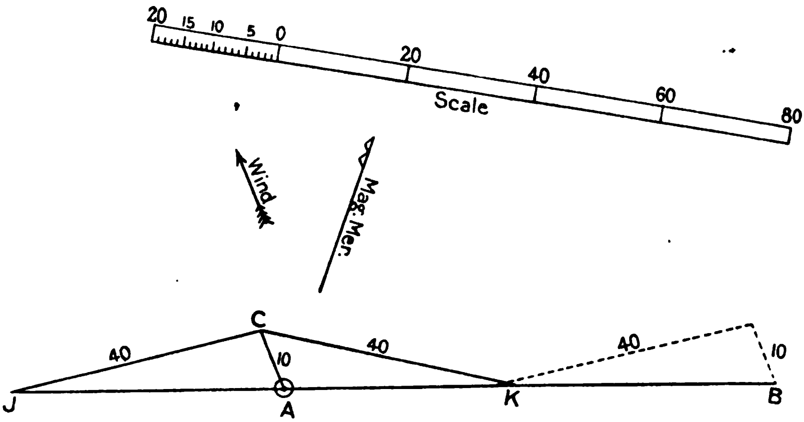


Fig. 31

In Fig. 31 let A be the starting point and AB the point she can reach.

To find the course out, draw AC to represent the wind in $\frac{1}{2}$ hr. and with centre C and radius $\frac{1}{2} \times 80$ or 40 miles, cut in the point K.

Then CK gives the course out, 83° (mag).

The ground speed out $= 2 \times AK = 71$ m.p.h.

Similarly on the return journey, her desired track is from B along BA, and the course and ground speed home can be found by the dotted lines, but it is simpler to plot the triangle starting from the point A, as AC has already been drawn to represent the wind.

Hence with C as centre and radius 40 miles, cut in J on BA produced.

Then CJ gives the course home, 237° (mag).

The ground speed home $= 2 \times AJ = 85$ m.p.h.

The time to turn $= \dfrac{85 \times 2}{71 + 85}$ hrs., or 1 hr. 5 mins.

The scouting range is the distance she covers in 1 hr. 5 mins. at 71 m.p.h. which is 77 miles.

Examples H_1, H_2, Appendix.

Note. If the air speed is large compared with the speed of the wind (say at least double), the direction of the wind does not much affect the scouting range, but has a large influence on the time to turn.

The greatest scouting range is obtained when the wind is at right angles to the direction of scouting, and the least is when the wind is in or from this direction.

Scouting Range by Inspection

[*Returning to the same base*]

The approximate value of the scouting range, sufficiently accurate for practical purposes, can be taken from the table on p. 53.

The error will not exceed about 5 per cent. if the number taken out is on the left side of the heavy zig-zag line, and about 10 per cent. if on the right.

Example. If scouting 10° (mag) with a wind of 40 m.p.h. from 180° (mag) and air speed 110 m.p.h., when should you turn in order to be back to your base in three hours?

Run down the 40 m.p.h. column until the 110 m.p.h. line is reached: the number is seen to be 49.

Hence the scouting range = 3 × 49 or 147 miles.

The ground speed out will be found to be 149 m.p.h.

Therefore the time to turn is after $\frac{147}{149}$ hours or just under an hour.

Note. The answer by the ordinary formula will be found to be 58 mins. and the scouting range to be 144 miles.

Examples H_1, H_2, Appendix.

To find the scouting range.

Take out the number corresponding to the air speed and speed of the wind, and multiply by the number of flight hours.

Air speed in m.p.h.	Speed of wind in m.p.h.									
	0–5	10	15	20	25	30	35	40	45	50
40	20	19	18	16	.	.	.	.	.	.
45	22	22	21	19	17	.	.	.	.	.
50	25	24	23	22	20	.	.	.	.	.
55	27	27	26	25	23	21	.	.	.	.
60	30	29	28	27	26	24	22	.	.	.
65	32	32	31	30	29	27	25	.	.	.
70	35	34	34	33	32	30	28	26	.	.
75	37	37	36	35	34	33	31	29	.	.
80	40	39	39	38	37	36	34	32	31	.
85	42	42	41	41	40	38	37	35	34	.
90	45	44	44	43	42	41	40	38	37	35
95	47	47	47	46	45	44	43	41	40	38
100	50	50	49	48	48	47	45	44	42	41
105	52	52	52	51	50	49	48	47	45	44
110	55	55	54	54	53	52	51	49	48	46
115	57	57	57	56	55	55	54	52	51	49
120	60	60	59	59	58	57	56	55	54	52

The scouting range divided by the ground speed out gives the time to turn (in hours).

Case (ii). ***Returning to a different base, or rejoining a ship in motion.***

Example. A seaplane is ordered to scout as far as possible in the direction 80° (mag) and to be back in three hours at another base, which is 330° (mag), 60 miles from her starting point. Her air speed is 74 m.p.h. and the wind is estimated to be from 20° (mag) at 25 m.p.h. After what interval should she turn, and how far can she scout?

Note. The second base might be a seaplane carrier which has steamed 60 miles in the three hours, in the direction 330° (mag).

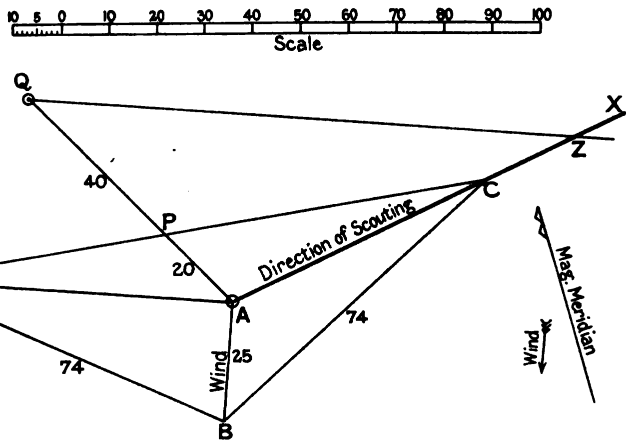


Fig. 32

From A, the starting point (see Fig. 32), lay off AB the wind in 1 hr., and cut in BC (74 m.p.h.) the air speed.

Then AC is the ground speed out, and is 58 m.p.h.

Divide the distance AQ between the two bases A and Q by three (the number of flight hours), i.e. take AP = one-third of AQ = 20 miles.

Note. If the wind and air distances are plotted for half an hour, the distance AP must also be half the above value.

Join CP and produce it.

With centre B and radius BC (74), the air speed, cut in BD.

Then AD is the ground speed in, and is 71 m.p.h.

Draw QZ parallel to AD, cutting AX, the track out, in Z.

Then AZ is the scouting distance = 81 miles, and ZQ is the track in.

The time to turn $= \frac{AZ}{AC} = \frac{81}{58} = 1$ hr. 24 mins.

The course out is given by BC and is 63° (mag).

The course in is given by BD and is 308° (mag).

Proof

Let AX be the direction of scouting from A, and Q the second base to which she is to return.

For simplicity assume that the aeroplane turns at T and returns to the point P along TP in one hour from leaving A, where

$$AP = \frac{\text{distance between the bases}}{\text{number of hours flight}},$$

then AT is the track out, and TP the track in.

Note. Draw QZ parallel to PT, cutting AX in Z. Then if the time of flight were three hours, she would scout 3 × AT (i.e. AZ) along AX, and return a distance 3 × TP (i.e. ZQ) along a line (ZQ), parallel to TP, reaching the second base (Q) in 3 × 1 hours, where AQ = 3 × AP.

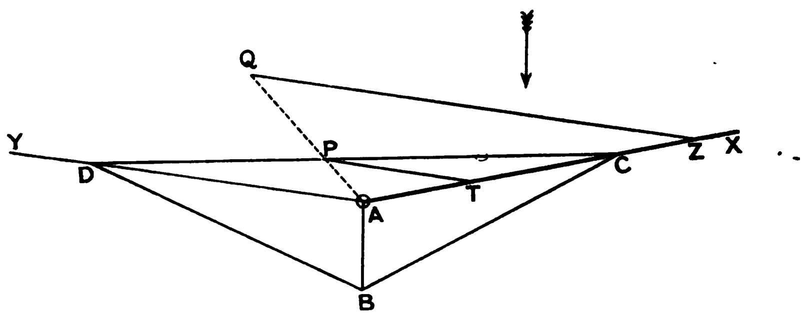


Fig. 33

Lay off AB, the wind in one hour, and cut in BC, the air speed, then AC is the ground she would cover out in one hour.

But she turns at T and is at P at the end of one hour.

Therefore she would cover TC at her ground speed *out*, in the same time that she covers TP at her ground speed *in*.

Therefore $\frac{CT}{TP} = \frac{\text{ground speed out}}{\text{ground speed in}} = \frac{CA}{\text{ground speed in}}$............(1).

From A draw AY parallel to TP (and therefore parallel to her track in) cutting CP produced in D. Join BD.

Then $$\frac{CT}{TP} = \frac{CA}{AD}.$$

Therefore from (1) AD must be her ground speed in.

Since AB is the wind and AD the ground speed, it follows that BD is the air speed.

Therefore the point D can be obtained by producing CP and cutting in the air speed.

Note. $\frac{DP}{DC} = \frac{AT}{AC}$. Hence the time to turn is also given by

$$\frac{DP}{DC} \times \text{number of hours flight.}$$

For Extra Notes

CHAPTER XI

COURSE AND DISTANCE CALCULATORS

The problems, Finding the wind, Shaping course allowing for wind, etc. all depend on the solution of a triangle.

The Course and Distance Calculator, or "C.D.C.," is an instrument which solves this triangle by means of jointed bars carrying sliding pointers to set to various lengths.

In the Campbell-Harrison C.D.C., the one chiefly used at present, a couple of pivoted arms represent two sides of the triangle, the third side being one of a series of parallel lines on a disc which can be turned round the central pivot.

The instrument is easily learnt if the ordinary triangle is plotted first, and the arms drawn in as shown in the following examples.

The points to bear in mind are:—

(1) The bevelled edge of an arm, or, in the smaller pattern, that edge which contains the bright spot on the moveable pointer, indicates a direction given or required.

(2) The direction of any one of the series of lines on the disc parallel to the central arrow line, is the same as that of the arrow.

(3) The junction of those two sides of the triangle whose lengths are known represents the centre of the disc.

Example (i). Find the wind, given

Course 84° (mag); air speed 80 m.p.h.

Observed track angle 71° (mag); observed ground speed 85 m.p.h.

[*The dotted triangle shows the following construction:—*

Lay off OA *the N.D. track, make* ON = *air speed* 80.
Lay off OB *the observed track, make* OG = *ground speed* 85.
Then NG *gives the wind.*]

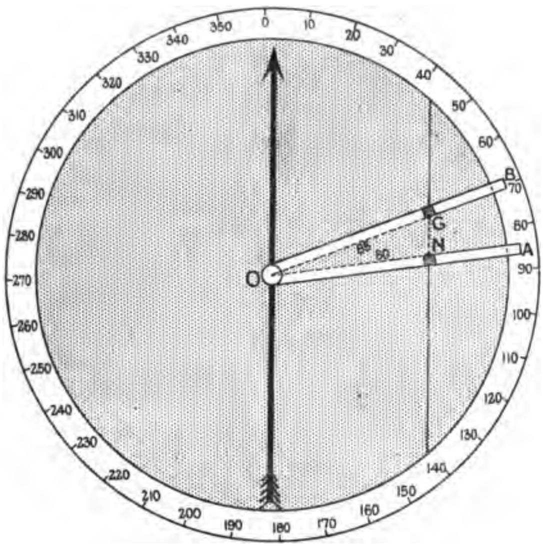


Fig. 34

As ON and OG are known, the centre of the disc must be at O. Hence the method of use is:—

Set one arm, OA, to course, 84°, and the pointer to air speed 80.
Set the other arm, OB, to observed track angle, 71°, and the pointer to ground speed 85.

Turn the disc until both pointers are on a line which is parallel to the central arrow line.

The arrow then gives the direction of the wind; in this case from 182° (mag).

The number of divisions between the pointers, multiplied by 10, gives the speed of the wind; in this case 30 m.p.h.

Example (ii). The desired track angle is 72° (mag). Find the course to steer, allowing for a wind from 135° (mag), 25 m.p.h. Air speed 80 m.p.h.

[*The dotted triangle shows the following construction:—*

G *is your position,* GP *the desired track.*
Lay off GK *the wind, and cut in* KC *the air speed.*
Then GC *gives the course and ground speed.*]

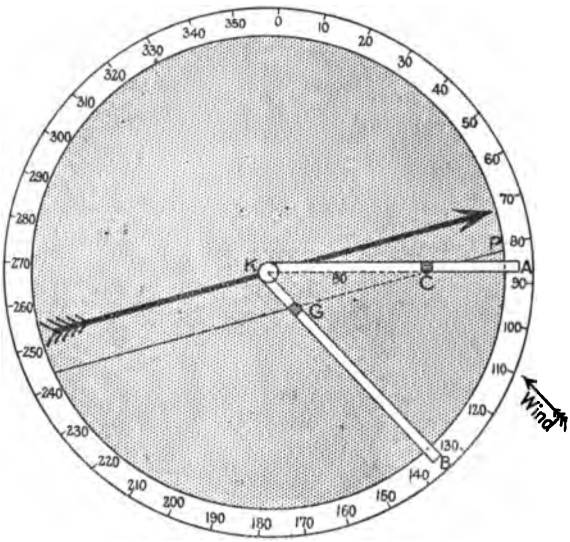


Fig. 35

As the lengths KG and KC are known, they must represent the arms, and their junction K must be the centre of the instrument.

Hence the method of use is:—

Set one arm KB in the direction *from* which the wind is blowing, and the pointer on it to the wind speed, 25.

Set head of arrow to desired track, 72°.

Set pointer on the other arm, KA, to air speed, 80.

Turn this arm KA until the pointer is on that particular line through G which is parallel to the arrow, taking care that from K to A is roughly in the direction of the arrow or desired track.

The direction of this arm KA is the course required; in this case 88°.

The number of divisions between G and C, multiplied by 10, is the ground speed; in this case 66 m.p.h.

Example (iii). A squadron bears 30° (mag), distant 40 miles, and is flying 100° (mag) at an air speed of 60 m.p.h. Your own air speed is 80 m.p.h. Find the course to join.

[P *is your position,* PE *the bearing of the squadron.*

Lay off PK, *the air speed of the squadron, in the opposite direction to that in which the squadron is flying, and cut in* KC, *your own air speed. Then* KC *gives the course to join, and* PC *gives the rate of approach.*]

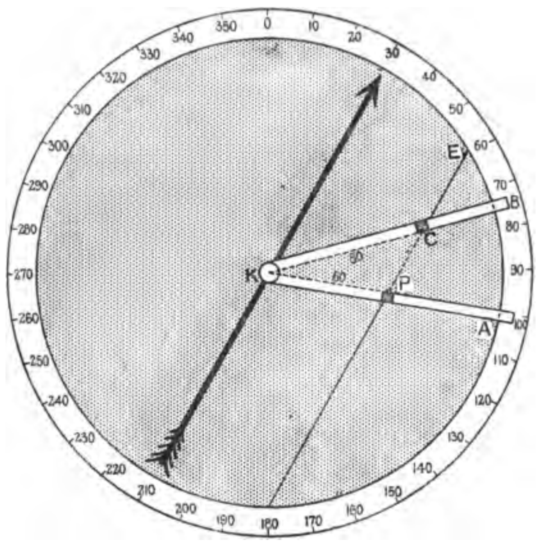


Fig. 36

As the lengths KP and KC are known, these must be the arms, and K must be the centre of the instrument.

Hence the method of use is:—

Set one arm KA to the course of the squadron, 100°, and the pointer, P, to the air speed of the squadron, 60.

Set arrow head to bearing of the squadron, 30°.

Set the pointer C, on the other arm KB, to your own air speed, 80, and turn this arm until the pointer C is on that particular line through P which is parallel to the arrow, taking care that from K to C is going somewhere towards the squadron or arrow head.

The direction of this arm KC gives the course to join; in this case 75°.

The number of divisions between P and C, multiplied by 10, gives the rate of approach; in this case 36 m.p.h.

Time taken to reach a place, Time taken when Scouting, etc.

Some patterns of C.D.C.'s are provided with an extra disc, acting as a slide rule for division and multiplication.

Rough results, generally accurate enough for the purposes required, can however be obtained without this special fitting, by using the arrow line for time (in minutes) and an arm (preferably that closest to the plate) for speed or distance.

Note. The principle made use of for this method is

$$\frac{\text{time required (in mins.)}}{60} = \frac{\text{distance covered}}{\text{speed}}.$$

Example (i). Required the time to cover 40 miles, at a ground speed of 73 m.p.h.

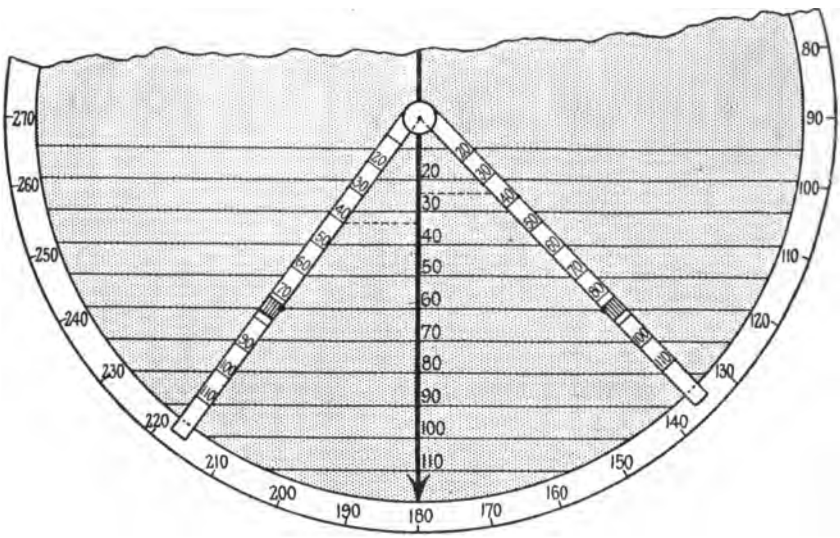


Fig. 37

Left-hand side of Fig. 37.

Set pointer on the arm to 73 and turn the arm until the pointer is on the line through 60 on the arrow.

Read off the mark on the arrow corresponding to 40 on the arm.

Answer, 34 minutes.

Example (ii). The estimated ground speed is 84 knots, what is the distance travelled in 24 minutes?

Right-hand side of Fig. 37.

Set pointer to 84, turn the arm until it is on the line through 60 on the arrow.

Read off the mark on the arm corresponding to 24 on the arrow.

Answer, 34 sea miles.

Example (iii). In a scouting problem, returning to your base in 3 hours, the ground speed out is found to be 35 m.p.h., and the ground speed in, 70 m.p.h. Find the time to turn and the scouting distance.

Set pointer to 35 + 70, or 105, and turn the arm until pointer is on the line through 60 on the arrow.

Read off the mark on the arrow corresponding to the ground speed *in*, 70, on the arm.

This is 40.

The time to turn is 40 mins. × number of hours flight = 40 × 3 = 120 mins.

The scouting distance is found by turning the arm till the pointer (set to 105) is on the line through 35 (ground speed *out*) on the arrow, and reading off the mark on the arrow corresponding to 70 on the arm.

This is 23.

Therefore

Scouting range = 23 miles × 3 = 69 miles.

For Extra Notes

CHAPTER XII

FIXING BY ANGLES

[*"Three point fix"*]

Suppose that at 9 a.m. from an aircraft, the angle between Ramsgate and Harwich is found to be 60°, and the angle between Ramsgate and Dungeness is 24° (see Fig. 38). Harwich being to the right of Ramsgate, and Dungeness to the left.

This observation would be written:—

9 a.m. Dungeness 24° Ramsgate 60° Harwich.

(The names of the places being written in the order in which they are seen from left to right.)

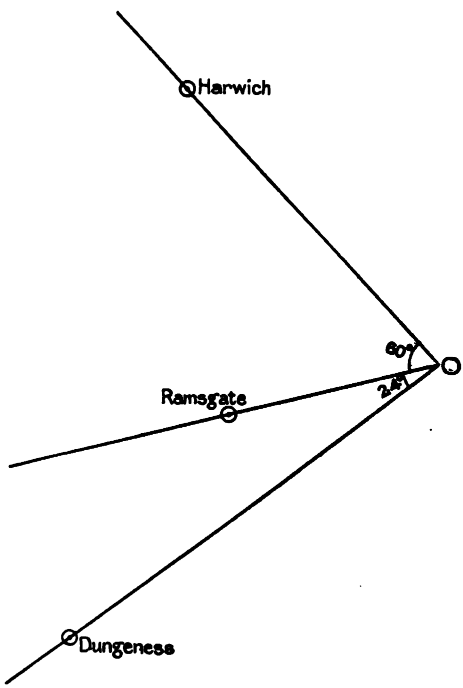


Fig. 38

The position of the aircraft can be plotted on the chart either by tracing paper, by the Douglas Protractor, or by a special instrument called the "station pointer."

In using the Douglas Protractor, consider the centre hole as the point O, and the arrow as representing the line from the aircraft to the middle place, in this case Ramsgate.

On the rough side of the protractor draw, in pencil, a line from O on the right-hand side of the arrow, making 60° with it to represent the line to Harwich, and a line on the left making 24°, to represent the line to Dungeness.

Note. Use the outer figures to draw the right-hand line, and the inner for the left.

Place the protractor, polished side downwards, with the arrow passing over the middle place, Ramsgate, noting that Harwich is on the right, and move it about until the two lines drawn on the protractor pass over the places to which they refer.

When the three lines pass over their respective places, prick through the centre hole. This will be the position of the aircraft.

Choice of Places

The accuracy of the fix will depend on the relative positions of the aircraft and the places.

To avoid the possibility of a bad fix, the middle place and the estimated position of the aircraft should be on the same side of the line joining the other two places.

Note 1. Observations must be practically simultaneous, and the height must be small compared with the distances.

Note 2. If the places are very distant, special charts have to be used if accuracy is required, since the straight lines on the chart or protractor only approximate to great circles for small distances.

Examples **K**, Appendix.

Explanation of the Method

Let the three places be A, B, C, and assume that the aircraft and the points A, B, C are all in a horizontal plane.

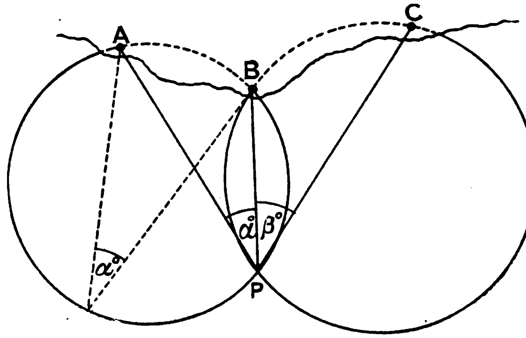


Fig. 39

Suppose the observation to be

$$A\ \alpha^\circ\ B\ \beta^\circ\ C.$$

Since the angle between A and B is found to be α°, the aircraft must be somewhere on the circular arc APB (Fig. 39), since angles in the same segment are equal.

Similarly if the angle between B and C is β°, the aircraft must be somewhere on the circular arc BPC.

The aircraft must therefore be at P, where the circles intersect.

If the two circles through A and B, and through B and C coincide, that is if the circle through A, B, and C passes through the aircraft, as in Fig. 40, then the position may be anywhere on the arc APP′C, and no fix is obtained: if the circle passes very near the aircraft, the fix will be poor.

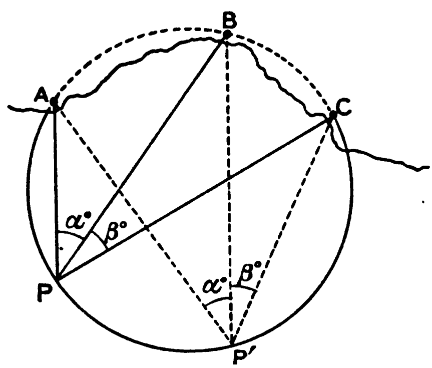


Fig. 40

It will be seen that if P and B are both on the same side of the line AC it is impossible for the circle through A, B, C to go through P.

For Extra Notes

CHAPTER XIII

THE MAGNETISM IN AN AEROPLANE

MAGNETISM

Certain iron ores possess the property of attracting and holding particles of iron, and are called "Natural Magnets": if a natural magnet, in the form of a thin straight wire, be freely suspended so as to be horizontal, it will always point in a definite direction at a given place, called Magnetic North, and the line in which it lies is called the Magnetic Meridian of the place.

The angle from True North to Magnetic North is called the Variation at the place.

The north-seeking end of a magnet is frequently called the red end, and is coloured red. The south-seeking end is blue.

Magnetised ends of opposite colours attract one another, and of the same colours repel each other.

Certain sorts of iron can be made to acquire and retain these magnetic properties, by methods which will be described later.

If a magnetic needle is freely suspended by a thread at its centre of gravity, and held at different points over a long magnet, it will be found to take up the various positions shown roughly

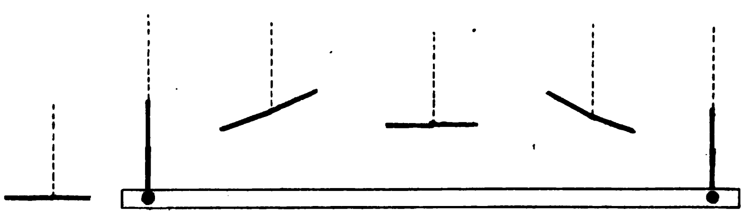


Fig. 41

in the figure (41), and there will be two points in the long magnet, above which the needle hangs vertically. The effective magnetism appears to reside in these two points, very near the ends. These will be called the Poles.

For the future, a magnet will be considered as a long thin rod with the poles at the ends, the part between them having no magnetic power.

Suppose now that the needle AB in Fig. 42 is held in the position shown. The pole P, being blue, attracts B and repels A, *both* causes tending to turn the needle in an anti-clockwise direction round its middle point O. Similarly the red pole P′ tends to turn the needle clockwise, and therefore the needle, if free to turn about O, will set itself according to the balance of these influences.

In the case shown in Fig. 42, the turning effect of P, the nearer pole, will be greater than that of P′, and the needle will point *towards* P, but not *directly* towards it.

Also, the effect of P on both the poles A and B being to turn the needle in the same direction, it is sufficient to consider the effect of the nearer pole of the magnet on, say, the red end of the needle.

It may be noted that if AB is sufficiently close, the forces may be powerful enough to cause it to move towards P.

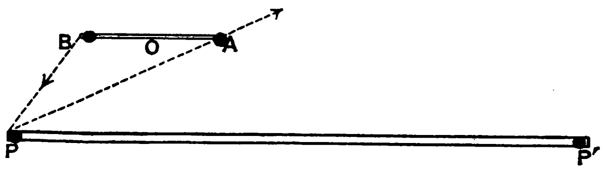


Fig. 42

Note. Except in a few positions of the compass needle with reference to the magnet, the nearer pole will have a greater effect than the further, and for simplicity of explanation, this will be assumed to be always the case.

The Earth's Magnetism

The magnetic forces exerted by the earth are roughly accounted for on the supposition that it contains a magnet whose blue pole is situated in Hudson Bay, and the red pole in South Victoria Land, both poles being below the surface. The straight line joining them does not however pass through the centre of the earth.

Any compass needle is so short compared with the distance to the poles, that the balance of the forces acting on it is quite insufficient to make it move towards the nearer pole, and only directs it.

The Dip

Since the blue and red poles of the earth are below the horizontal line at any place (see Fig. 43), the needle will always set itself, or "dip," at some angle to the horizon, if freely suspended from its middle point, except at those places where it is acted on equally by both poles.

The angle it makes with the horizon when it lies in the plane of the magnetic meridian is called the dip.

This tendency is counteracted, as long as the card remains horizontal, by the method used to suspend the needle, but is of great importance when an aeroplane is banking.

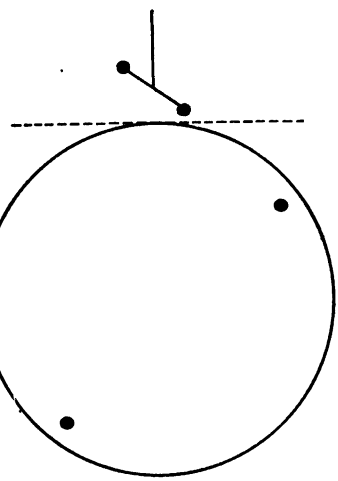


Fig. 43

Permanent and Induced Magnetism

It is convenient to consider that the iron and steel used in the construction of aircraft is either "hard" or "soft."

Hard iron is not easily magnetised, but retains its magnetism unaltered, that is, it possesses "permanent magnetism."

It can be made magnetic

(1) By rubbing it with a magnet.

(2) By being hammered when in any position other than one at right angles to the line of dip.

(3) By winding a wire round it and passing an electric current through the wire. Since the colour of the magnetism thus produced depends on the direction of the current, the wire and return wire of any electric lead should be twisted together if near the compass, in order to neutralise their separate effects.

Soft iron instantaneously becomes magnetised when near a magnet, and when in any position other than one at right angles to the line of dip, but loses this "induced magnetism" directly the inducing force is removed.

No iron, however, is entirely hard or entirely soft.

The strength, or magnetic force, exerted by a magnet is unaffected by ordinary changes of temperature, but is all lost and does not afterwards return, if the magnet is raised to a dull red heat.

The power of a magnet is reduced if it becomes rusted.

When a magnet is broken into any number of pieces, each portion becomes a magnet, but of less power than the original one.

The Magnetism in an Aeroplane

Little soft iron is at present used in the construction of aeroplanes, so that it will only be necessary to consider the effect of the permanent magnetism given to the hard iron by the hammering it gets in being built.

The combined effects of the various magnetised steel rods, etc., may be represented by a single magnet, which, in most machines, will have both its poles forward of the compass, as in Fig. 44.

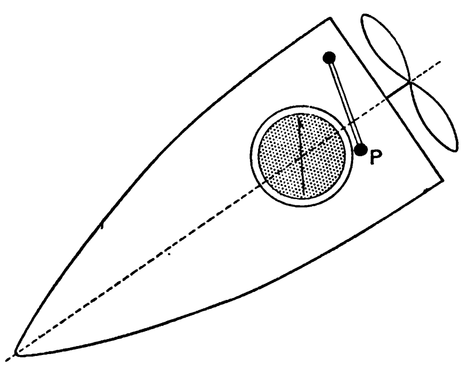


Fig. 44

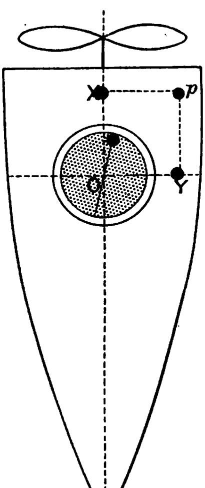


Fig. 46

Consider the effect of the nearer pole of this magnet on the red, or north-seeking end of the compass needle at O, and assume the aeroplane to be horizontal.

Suppose that the nearer pole of the magnet is blue, as in Fig. 44, and that it is below the compass level. Then the attractive force acting on the red end of the needle is along OP, and is the same as a force along the horizontal line O*p* and a vertical force downwards on O, as in Fig. 45.

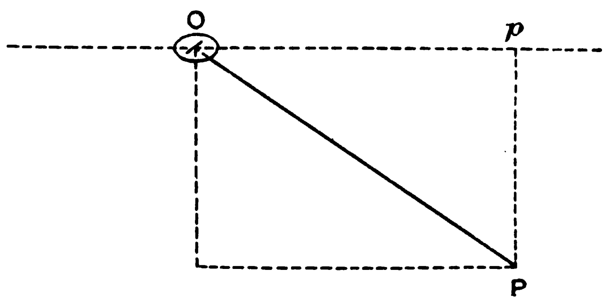


Fig. 45

Since the needle is constrained to remain horizontal, the vertical force can have no effect, and it is only necessary to consider that there is a blue pole at *p*.

This blue pole *p* will attract the red end, and can be replaced by a blue pole at X in the fore and aft line, ahead of the compass, and another blue pole at Y, on the starboard beam, or right-hand side looking forward, as shown in Fig. 46.

Note. In some positions of the magnet, as referred to on p. 70, the need of considering both poles may result in a red pole either forward or on the beam; but the explanation of the method of correction is greatly simplified (without affecting the principle) by considering only a single pole.

Method of Correcting for Permanent Magnetism

If in Fig. 46 the craft is supposed to be pointing magnetic north, then the blue pole X is adding its power to that of the earth in causing the needle to point to the magnetic north, and cannot give rise to any deviation.

Any deviation therefore observed in this position must be due to the pole Y, and can be corrected by placing magnets

across the compass, until the needle points exactly to magnetic north. This corrects for the pole Y.

Thus if the needle shows 330° when the aeroplane is pointing N. (mag), as in Fig. 46, it indicates that the pole Y is blue, since the north or red end of the needle is pulled 30° towards the east, and therefore magnets must be placed in the tube across the compass, so that *when in position,* the red ends are to starboard and annul the blue pole Y.

It should be noted that when the ends of the compensating magnets are held at the end of the tube *before* being pushed home, the deviation will be increased.

Similarly, when the aircraft is placed to head magnetic east, the deviation of the needle is due to the pole X, and is corrected by placing magnets in the fore and aft direction. In the case shown in Fig. 47, the red poles will be forward of the centre of the compass. This corrects for the pole X, and the compass is now roughly "adjusted."*

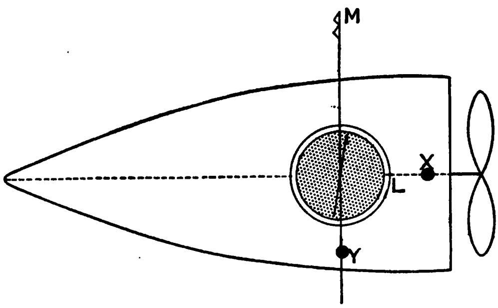


Fig. 47

Though the deviation on north and east has been taken out, it must not be thought that there will be no deviation for other directions.

It is not practicable to get rid of the effect of the soft iron, and it is therefore necessary to find the deviations due to it, and allow for them when correcting courses and bearings.

Note. Assuming the aeroplane is horizontal, and that it is used in the same region, so that the earth's magnetic force does not alter appreciably, any vertical soft iron will acquire and continue to possess magnetic power indistinguishable from the permanent variety, as long as the two conditions are maintained.

It follows therefore, that the adjustments dealt with above really compensate for both permanent magnetism and the induced magnetism from vertical soft iron.

* A closer adjustment is made by next taking out *half* the deviation now found to exist on South, and then *half* that on West.

CHAPTER XIV

ADJUSTING THE COMPASS

Practical Adjustment

The process of adjusting the compass of an aeroplane, and of "swinging" for deviation, will now be shown by the following example.

The machine in question was a Sopwith Scout, with a rotary engine.

The compass was of the vertical type, placed about 1 foot below a machine gun fixed rigidly in the fore and aft line.

A spot O is chosen, and points on the ground bearing N., N.E., E., S.E., S., S.W., W., and N.W. (all magnetic) from the point O are found by means of a compass, and marked by pegs or other means.

Care must be taken that there is no iron or steel, etc., in the immediate neighbourhood.

The testing ground thus marked, is shown in Fig. 48, the lines from N.E. to S.W., etc., being either painted or indicated by strings.

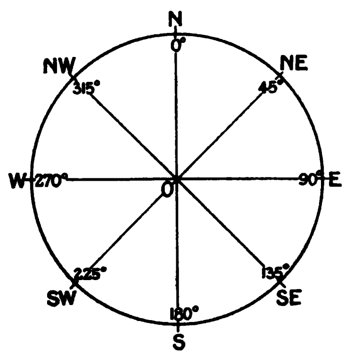


Fig. 48

The central fore and aft line of a machine is then determined by hanging a plumb line from the nose and another from the tail.

When the aeroplane was placed with the fore and aft line magnetic north and south, and the machine's nose to the north, as in Fig. 49, the north-seeking or red end of the needle was seen to be to the right of the lubber line L, which now indicates magnetic north, the reading being 350°.

The needle must therefore be made to move to the left, so that magnets must be put across the compass in the tubes fitted for this purpose, with their red poles to starboard (i.e. on the right).

It was found that one magnet thus placed was enough to make the reading 0° or 360° (see Fig. 50).

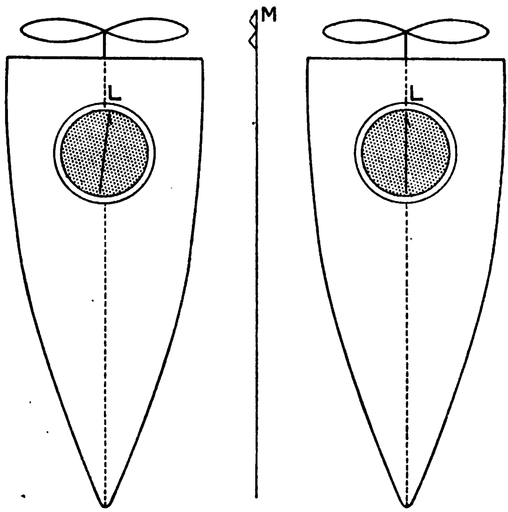


Fig. 49
(before correction)

Fig. 50
(after correction)

The machine was now placed to point magnetic east, as in Fig. 51, and the reading was observed to be 60°, whereas, if there were no deviation it ought to be 90°.

Magnets were put in the fore and aft tubes, red poles forward, until the reading was 90°. It was found that four magnets and half a magnet were required, the needle then indicating magnetic north as in Fig. 52.

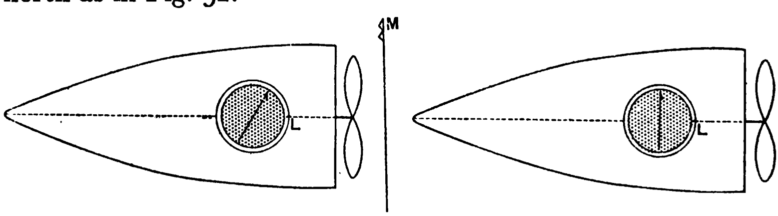


Fig. 51
(before correction)

Fig. 52
(after correction)

The compass has now been adjusted, and the next matter is to find the compass directions of the nose which correspond to the various magnetic directions and, if wanted, to deduce the deviation in each case.

Note. In carrying out these adjustments, and in "swinging" (as described below), care must be taken that no steel articles, etc. are carried in the pocket or placed anywhere near the compass. All instruments, etc. should be in position, and if it can be done, the engines should be running.

Swinging

The aeroplane was placed with the fore and aft line in each of the following magnetic directions, 0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°, and the corresponding compass direction of the nose in each case, i.e. the readings of the lubber line, was found to be as follows:—

Mag direction of nose	Direction of nose by compass
N. 0°	0°
N.E. 45°	49°
E. 90°	91°
S.E. 135°	130°
S. 180°	178°
S.W. 225°	218°
W. 270°	272°
N.W. 315°	312°
N. 360°	360°

Any intermediate Magnetic Course can be converted to compass from this table by rough interpolation, but it is evidently much more convenient to tabulate the results for every 10°, especially when the deviation is at all large.

The results are shown in the Conversion Table (1) or (2) on the inside cover. The method of use is given on p. 23.

The deviation in any case is the difference between the magnetic and compass course, and is named East or West from the rule "Compass Least, Deviation East."

Thus 135° (mag) is seen to correspond to 130° (comp.).

The Deviation for either of these is therefore 5° E.

Construction of a Conversion Table for every 10°

This is done by proportion.

Thus in the case considered, 45° (mag) corresponds to 49° (comp.),
and 90° (mag) corresponds to 91° (comp.).
For a difference of 45° (mag) the compass difference is 42°.

„	„	5° (mag)	„	„	$\frac{42^\circ}{9}$ or 5°.
„	„	10° (mag)	„	„	$\frac{84^\circ}{9}$ or 9°.

Hence 50° (mag) will be 49° + 5° (comp.), i.e. 54° (comp.).
60° (mag) will be 54° + 9° (comp.), i.e. 63° (comp.).
etc.

The interpolation table gives these successive numbers 5°, 9°, ... for various compass differences, and by its use it will be found that two minutes is sufficient to write down the whole series of compass courses corresponding to every 10° (mag).

It should be noted that when Column 1 is used, the compass course in the original table (for 0°, 90°, 180°, or 270°) is written down in the required series and the four given numbers applied in succession.

When Column 2 is used, the compass course for 45°, 135°, 225°, or 315° is *not* written down, but the first (small) number is added to the *compass* course corresponding to this magnetic course.

Example. Construct the table between 90° and 180°, using the data on p. 77.

Between 90° and 135° (mag) the difference of the compass readings is 39°.

The numbers (from column 1 of the interpolation table) are 8, 9, 9, 9.

For 90° (mag) the comp. reading is 91°, and adding 8, 9, 9, 9 successively to this, we obtain 99°, 108°, 117°, 126°, which will be the comp. readings corresponding to 100°, 110°, 120°, 130° (mag).

Between 135° and 180° (mag) the difference of the compass readings is 48°.

The numbers (from column 2) are 5, 10, 11, 11.

For 135° (mag), the comp. reading is 130°, and adding 5, 10, 11, 11, successively to this, we obtain 135°, 145°, 156°, 167°, which will be the comp. readings corresponding to 140°, 150°, 160°, 170° (mag).

INTERPOLATION TABLE

Difference of Compass Reading for 45° difference Magnetic	Successive numbers to be added to the Compass Course: (1) Mag. Co. 0° to 45°, 90° to 135°, 180° to 225°, 270° to 315°	Successive numbers to be added to the Compass Course: (2) Mag. Co. 45° to 90°, 135° to 180°, 225° to 270°, 315° to 360°	Difference of Compass Reading for 45° difference Magnetic	Successive numbers to be added to the Compass Course: (1) Mag. Co. 0° to 45°, 90° to 135°, 180° to 225°, 270° to 315°	Successive numbers to be added to the Compass Course: (2) Mag. Co. 45° to 90°, 135° to 180°, 225° to 270°, 315° to 360°
25°	5. 5. 6. 6.	3. 5. 5. 6.	45°	10. 10. 10. 10.	5. 10. 10. 10.
26°	5. 6. 6. 6.	3. 5. 6. 6.	46°	10. 10. 10. 11.	5. 10. 10. 10.
27°	6. 6. 6. 6.	3. 6. 6. 6.	47°	10. 10. 11. 11.	5. 10. 10. 11.
28°	6. 6. 6. 7.	3. 6. 6. 6.	48°	10. 11. 11. 11.	5. 10. 11. 11.
29°	6. 6. 7. 7.	3. 6. 6. 7.	49°	11. 11. 11. 11.	5. 11. 11. 11.
30°	6. 7. 7. 7.	3. 6. 7. 7.	50°	11. 11. 11. 11.	6. 11. 11. 11.
31°	7. 7. 7. 7.	3. 7. 7. 7.	51°	11. 11. 11. 12.	6. 11. 11. 11.
32°	7. 7. 7. 7.	4. 7. 7. 7.	52°	11. 11. 12. 12.	6. 11. 11. 12.
33°	7. 7. 7. 8.	4. 7. 7. 7.	53°	11. 12. 12. 12.	6. 11. 12. 12.
34°	7. 7. 8. 8.	4. 7. 7. 8.	54°	12. 12. 12. 12.	6. 12. 12. 12.
35°	7. 8. 8. 8.	4. 7. 8. 8.	55°	12. 12. 12. 13.	6. 12. 12. 12.
36°	8. 8. 8. 8.	4. 8. 8. 8.	56°	12. 12. 13. 13.	6. 12. 12. 13.
37°	8. 8. 8. 9.	4. 8. 8. 8.	57°	12. 13. 13. 13.	6. 12. 13. 13.
38°	8. 8. 9. 9.	4. 8. 8. 9.	58°	13. 13. 13. 13.	6. 13. 13. 13.
39°	8. 9. 9. 9.	4. 8. 9. 9.	59°	13. 13. 13. 13.	7. 13. 13. 13.
40°	9. 9. 9. 9.	4. 9. 9. 9.	60°	13. 13. 13. 14.	7. 13. 13. 13.
41°	9. 9. 9. 9.	5. 9. 9. 9.	61°	13. 13. 14. 14.	7. 13. 13. 14.
42°	9. 9. 9. 10.	5. 9. 9. 9.	62°	13. 14. 14. 14.	7. 13. 14. 14.
43°	9. 9. 10. 10.	5. 9. 9. 10.	63°	14. 14. 14. 14.	7. 14. 14. 14.
44°	9. 10. 10. 10.	5. 9. 10. 10.	64°	14. 14. 14. 15.	7. 14. 14. 14.

Examples 27

(1) Avro machine, Gnome rotary engine, Compass (pattern 259) in front of forward seat.

The compass readings for the eight magnetic directions, N., N.E., etc., were, after adjustment, 0°, 42°, 90°, 139°, 180°, 220°, 270°, 319°.

Construct a conversion table for every 10°.

(2) R.E. machine, Sunbeam stationary engine, Compass (pattern 255) in front of forward seat between two steel struts.

The compass readings for the eight magnetic directions N., N.E., etc., were, after adjustment, 5°, 45°, 90°, 130°, 179°, 240°, 270°, 310°.

Construct a conversion table for every 10°.

EFFECT OF BANKING (*North Latitudes*)

When an aeroplane is banked on a turn, the compass card takes up the same inclination to the horizon as the machine, and, taking the extreme case of a vertical bank when heading

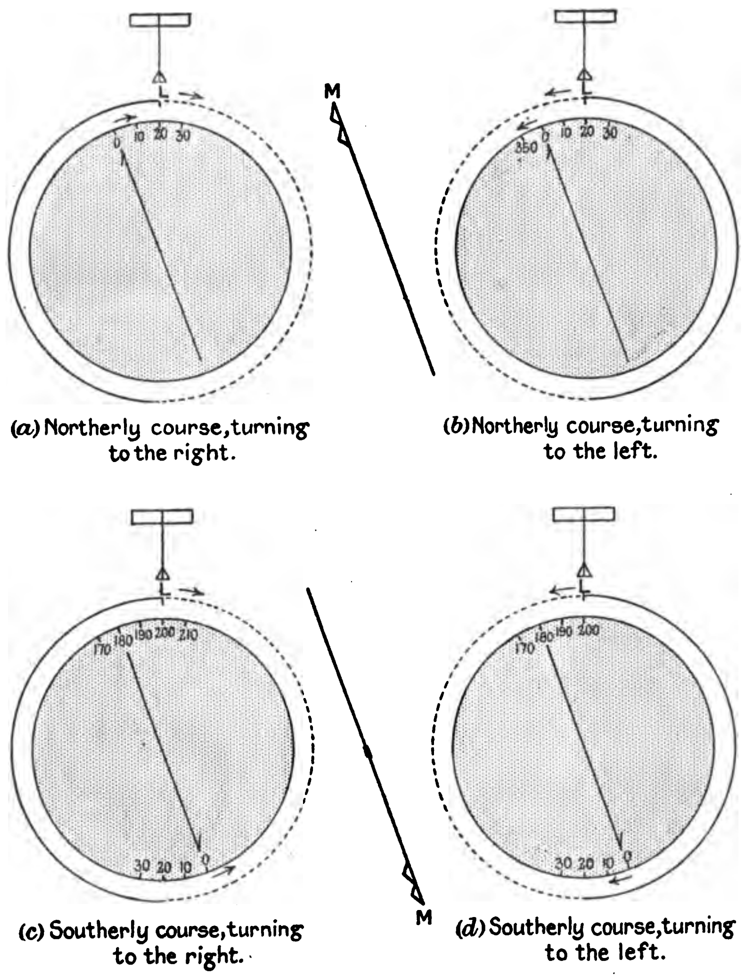


Fig. 53

North (mag) in Northern Latitudes, the needle will be perfectly free to set itself as explained in the section on Dip (p. 71).

In every bank, the north end of the needle or card tends to

move downwards, though this tendency is strongest when the course is north or south.

Consider now the aeroplane and compass shown in Fig. 53 (*a*): suppose that the course is 20°, and it is required to turn 10° to the right.

If the aeroplane is on the ground, it is evident that L has to move 10° to the right, and therefore the new reading will be 30°.

But in the air, the machine has to be banked to make the turn, so that the dotted part of the card is lower than the other. The end O of the needle or card therefore moves downwards, i.e. to the right or clockwise in this case, and the reading when the aeroplane has turned 10° will be less than 30°, say 25° (thus indicating a turn of 5° only); if O moves faster than L, the reading will even be less than the original, say 15°, apparently indicating that the machine has turned 5° to the *left*.

By taking the other figures in a similar way, it will readily be seen that when making a turn from a Northerly course (i.e. between 0° and 90°, or 270° and 360°) the amount of the turn shown by the compass is always too small, and may sometimes be in the wrong direction.

In turning from a Southerly course (90°–270°), the amount of the turn shown by the compass is too large, but is always in the correct direction.

The strength of the tendency for the north point of the needle to move downwards will clearly be decreased if the magnetic power of the needle is decreased, but on the other hand it takes a long time to settle down to the course steered, and is readily disturbed.

Instances are on record where weak needles have gone round and round on starting up the engine.

Compasses fitted with strongly magnetised needles are practically "dead beat," i.e. they show the course almost at once, and there is no great error in turning except when making a fairly steep bank from nearly North or South.

CHAPTER XV

WIND AND WEATHER

The pressure of the air on any surface is due to the weight of the vertical column of air above it, and therefore decreases with increasing altitude.

This pressure is exerted equally in all directions and at the sea level is roughly 15 lbs. to the square inch.

It is measured by the **Barometer**, which shows the height of that column of mercury which is equivalent in weight to a column of air, of the same horizontal section.

The pressure is expressed either in inches of mercury or in millibars (mb.), 1000 mb. corresponding to 29·53 inches. The average pressure at sea level is 1010 mb. or 29·83 inches.

The average decrease in pressure due to increasing altitude is about 1 inch or 33 mb. for 1000 feet.

Note 1. The extreme readings recorded in the British Isles are 31·11 and 27·33.

Note 2. The French weather reports give the pressure in millimetres; to convert millimetres into millibars add one-third.

Air pressure may also be measured by balancing it against a spring: this is done in the **Aneroid Barometer**, in which a small circular metal box exhausted of air is kept extended by a spring, while the pressure of the air tries to make it collapse; any variation of pressure will cause the side of the box to move, and this movement is shown by a hand on a dial graduated in inches or millibars or both.

Altimeter. This is an Aneroid graduated in feet, showing the altitude attained by the decrease in air pressure; it must be set to 0 before leaving the ground. Since at any moment of the flight, the original pressure of the air at starting has probably altered, and is not the same as at the point at the sea level directly under you, the reading is only approximate.

The altimeter gives the height above the *level of the starting point*; if therefore you are flying over hills and valleys, your

height above the ground may differ considerably from that shown by the altimeter.

An altimeter does not respond at once to change of altitude; this is known as "creep error."

Note. For experimental work, a correction has to be made for temperature.

AIR SPEED INDICATOR

The air speed indicator is on the principle of the aneroid, except that the box is not exhausted of air; the interior and exterior are in connection with two tubes, one of which receives the pressure due to the stream of air caused by the motion of the machine, while the other remains at the pressure corresponding to the altitude; the air speed is obtained from the difference of these pressures, and is recorded on a dial.

At high levels the readings of the instrument are too low, owing to the reduction of difference of pressure, which depends on the density; on some instruments this correction can be made, and the true speed read off, by means of an outer dial.

Note. This correction is $\frac{VH}{60}$, where V is the speed as read, H the altimeter reading in thousands of feet: so that if $V = 100$, and the altimeter reads 6000, then $H = 6$, and the correction is $\frac{100 \times 6}{60}$, or 10 m.p.h.; the correct speed is therefore about 110 m.p.h. The instrument is also subject to error due to temperature and leakage.

TEMPERATURE

Temperature indicates the intensity of heat in a place or body. It is measured by the expansion or contraction of a column of mercury in the Thermometer. Two scales are used; the Fahrenheit (F.), and the Centigrade (C.), shown in Fig. 54.

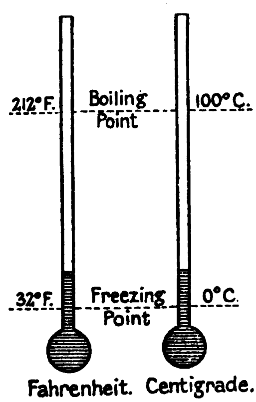


Fig. 54

Heat can pass from one place to another, or from one body to another, in three ways:—

(1) It can be carried; thus a room may be heated by conveying a current of warm air into it. ["*Convection*."]

(2) It can warm a neighbouring body, which in its turn can pass the

heat on to another; thus if we heat one end of a poker in the fire the other end soon becomes hot. ["*Conduction.*"]

(3) It can be "radiated"; it is in this way that the sun warms the earth, or a fire warms a room. ["*Radiation.*"]

Hot air is lighter than cold; therefore a mass of hot air will tend to rise amid cooler air.

Humidity or Dampness

All air contains invisible water vapour; the hotter the air the more vapour it can carry. But no air can carry more than a certain quantity depending on the temperature; when it has all it can carry it is said to be saturated. Any further attempt to make it more damp results in formation of cloud or fog; similarly if we cool saturated air some of the water in it becomes visible as a cloud.

Whether cloud will form depends more on the relation of the amount of water vapour actually present at the time, to the greatest amount that could be present at the same temperature, than on the total quantity present. This "relative humidity" is found by means of the wet and dry bulb thermometer.

The greater the difference between the readings of the two thermometers the less is the relative dampness; the less the difference, the greater the relative dampness.

Clouds

There are four main types of clouds :—

(1) Cirrus. Thin and wispy—composed of ice particles—height 25,000 to 30,000 feet. "Mares' tails."

(2) Cumulus. Lumps like cotton wool—composed of water particles—up to 25,000 feet—formed at the top of ascending air currents.

(3) Stratus. Flat, spread out clouds. Resembling fog, but not resting on ground.

(4) Nimbus. Clouds from which rain or snow is falling.

Formation of clouds.

(1) Warm saturated air blows over cold sea or land; e.g. Newfoundland fog, due to the wind from the Gulf Stream blowing over cold water, or again, when warm currents pass over mountains, especially if snow covered: these are usually stratus.

(2) Rising air expands, cools, and its moisture condenses; usually cumulus.

(3) Air forced to rise by passing over a mountain; this cools and parts with its moisture as in (2).

(4) Air may part with its heat by radiation, and therefore cannot contain so much moisture.

(5) Mixing of two currents at different temperatures.

LOCAL AIR CURRENTS CAUSING "BUMPS"

Where local differences of temperature exist, upward and downward currents of air will occur and cause "bumps" such as shown (in an exaggerated form) in the following figures.

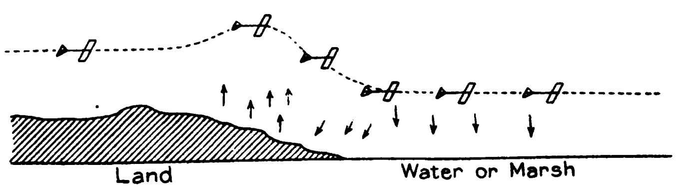


Fig. 55
Water colder than the surrounding land

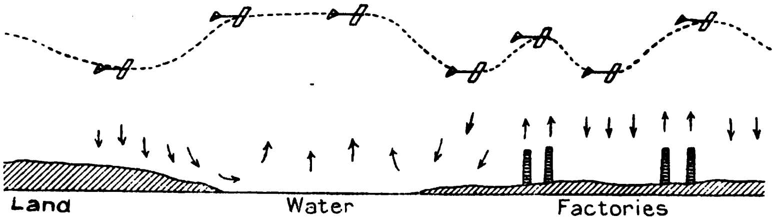


Fig. 56
(a) Water warmer than the land **(b) Over factory chimneys, etc.**

Note. Moist air ascending has no noticeable effect when there is no difference of temperature.

These bumps are rarely perceptible at heights above 15,000 feet, and are usually less noticeable at night.

Bumps over ridges of hills, cliffs, large sheds, etc., may be due also to a different cause, viz., eddy motion in the air (Fig. 57).

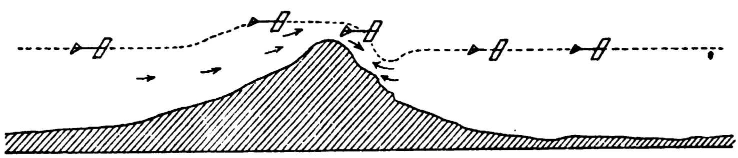


Fig. 57

Eddies over a ridge

Over a sandy desert, and in hot climates generally, conditions are frequently very bumpy, especially close to the ground.

In the immediate vicinity of patchy clouds, above or below, there will be upward and downward currents due to difference of temperature, and "bumps" will be found. This is especially noticeable in clouds of the cumulus type, which are caps of ascending currents, and also in thunder clouds.

Land and Sea Breezes

Land and sea breezes are caused by difference of temperature. The earth gets heated up more quickly during the day and also loses its heat more quickly during the night, we therefore get a sea breeze (i.e. a breeze from the sea) in the daytime, and a land breeze (i.e. a breeze from the land) during the night.

Such breezes are found from 10 to 15 miles from the coast, and up to 1000 feet from the ground.

These may be annulled by general prevailing conditions.

Wind

Isobars are curves drawn through places where the pressure is the same at a definite time.

These pressures have been corrected for height above sea level, temperature, and latitude.

The isobars are drawn for differences of pressure of 5 mb.

Buys Ballot's Law. In the N. Hemisphere "Face the wind, then the pressure will be lower on your right hand." In the S. Hemisphere, the reverse will be the case.

The gradient wind.

This wind is experienced at heights 2000–3000 feet over the land and 300–500 feet over the sea.

At these heights and over its direction is roughly along the isobars.

Its velocity at any place is given, in m.p.h., roughly for home latitudes by dividing 4600 by the distance in miles between two consecutive isobars between which the place lies.

Its speed in *knots* is given by dividing 3500 by the distance apart in nautical miles.

A table such as the following affords a rough means of finding the upper wind from the surface wind in Northern latitudes; but varies slightly according to locality.

Height	1000 ft.	1500 ft.	2000 ft.
*Wind veers** ...	10°	15°	20°
Approx. velocity of upper wind	1½ times the surface wind	Twice the surface wind	Twice the surface wind

Example. If the wind at the surface is from 75° at 20 m.p.h., the upper wind at 2000 feet will be roughly from 95° at 40 m.p.h.

Note. A simple way of remembering this is that the direction and speed increase with the height.

* If the measure of the wind's direction increases, it is said to "veer": if it decreases, it is said to "back." Thus if the wind at first is "from 45° (true)," and later "from 60° (true)," it has veered 15°. If at first "from 0° (true)," and later "from 330° (true)," it has backed 30°.

With westerly winds the force of the wind above the gradient wind may be greatly increased with altitude.

With easterly winds at the surface, the wind at high altitudes frequently blows in an altogether different direction.

Examples 28

(1) The surface wind was from 150° (true) at 20 m.p.h. What would you expect the wind to be (*a*) at 1500 feet, (*b*) at 2000 feet?

(2) You found from observation that the wind at 2000 feet was from 210° (mag) at 30 m.p.h.

What wind would you expect on descending to 1000 feet, and also at the surface?

(3) The surface wind was from 350° (true) at 20 m.p.h.

Calculate the velocity of the wind at (*a*) 1000 feet, (*b*) 2000 feet.

(4) The wind at 2000 feet was observed to be from 10° (true) at 20 m.p.h.

What would you expect the surface wind to be?

(5) The surface wind at a place was reported to be from 225° (true) at 18 m.p.h.

Give the direction (mag) and speed of the wind at a height of 1000 feet over this place. Variation 15° W.

The following, called the "**Beaufort Scale,**" gives a rough method of estimating the velocity of the wind. (Only the Nos. 3, 4, 5, 6 are given.)

Beaufort Number	Name	Indication	Average velocity in m.p.h.
3	Gentle breeze	Leaves and small twigs in constant motion: wind extends a light flag. Smacks begin to heel over	10
4	Moderate breeze	Raises dust and loose paper. Small branches are moved. Smacks carry all canvas with good list	15
5	Fresh breeze	Small trees in leaf begin to sway. Wavelets form on inland waters. Smacks shorten sail	20
6	Strong breeze	Large branches in motion: whistling heard in telegraph wires. Umbrellas used with difficulty. Smacks have double reef in mainsail	25–30

DEPRESSIONS, ETC.

A Cyclonic Depression, or "Low," consists of isobars more or less oval (as in Fig. 58). The pressure decreases towards the centre round which the air moves in an anti-clockwise direction in the N. Hemisphere and in a clockwise direction in the S. Hemisphere. The whole system moves approximately in an E.N.E. direction in Northern Latitudes.

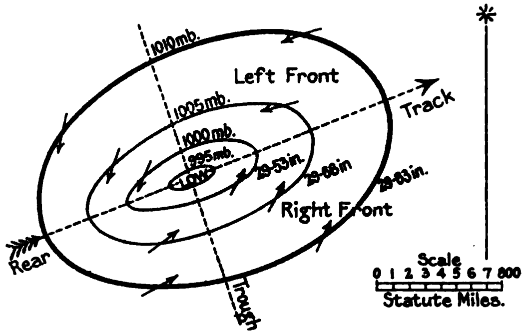


Fig. 58

At the surface the wind is inclined about 30°–40° to the isobars in the N.E. quadrant; and 15°–25° in the S.W. quadrant.

Note. Approach of a depression usually marked by rising temperature in winter; but in summer by a fall in temperature owing to cloudiness.

Winter depressions; deeper and of longer duration than summer. The N. side of the track may be accompanied by heavy rain. On the S. side the shift to N.W. in rear of trough may be accompanied by increased wind force and heavy squalls of rain or snow. These N.W. winds may last a considerable time. If cold, snow may take the place of rain.

In summer, depressions are not so frequent and do not last so long as in winter. On the N. side rain may continue some time after the passage of the trough. On the S. side after the passage of the trough rains occur in short squalls, and the N.W. winds are generally not high nor of long duration.

In Home Latitudes the observer is generally to the S. of the track so that the observed sequence of events is something as follows:—

Front. 1. Cirrus and cirro-cumulus clouds found. Temperature falls in summer, rises in winter. Dampness increasing.

2. Wind S.E. or S. Cloudiness increasing. Cirro-stratus abundant.

3. Gloomy, overcast, drizzling rain. Wind tending to veer to S.W. with strato-cumulus clouds, and often much rain.

Trough. 4. Severe squalls. Wind changing suddenly to W.S.W., W., or N.W., marking passage of line of trough.

Rear. 5. Good visibility. Bright weather with frequent heavy squalls of wind and rain. Temperature is relatively low and air is drier.

Secondary depression or Secondary Cyclone. In N. latitudes is generally found on the S. side of a depression and generally in rear of trough. Isobars take a slight bend outwards marking position of a small centre of pressure (see Fig. 59).

Generally marked by rains rather than by heavy winds.

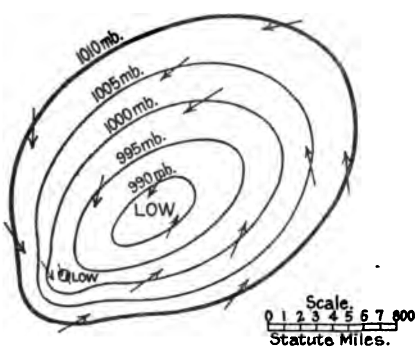


Fig. 59
A secondary depression

V-depression. A development of the secondary: the isobars extending out a long way in the shape of a V (see Fig. 61). They are frequently associated with a Line Squall occurring along the line of trough. This is a squall accompanying a sudden increase of pressure which under certain conditions may occur simultaneously over a long line of country.

Line squalls are of short duration but are marked by exceedingly high wind.

They are preceded by S.W. winds and damp air accompanied by heavy rain or hail with a large drop in temperature and the passage of a long line or arch of dark cloud. As the trough passes the wind shifts more or less suddenly to N.W. Frequently they are accompanied by thunderstorms.

Thunderstorms. Characteristics: An immense cumulo-nimbus cloud accompanied by heavy rain, marked fall of temperature and a peculiar outrushing squall of wind preceding the rain. Temperature rises before a thunderstorm and reaches a maximum just before; it drops slightly when sun is obscured by clouds, but a heavy fall occurs when storm breaks. Later the temperature rises again.

Wind is light and from S. As storm approaches, wind shifts to E., and blows towards storm; this is suddenly replaced by the squall wind blowing directly from the storm. After the storm it drops and shifts back to S.W. or S.

Anticyclone. Consists of isobars more or less oval (as in Fig. 60), but generally farther apart than in a depression. Wind

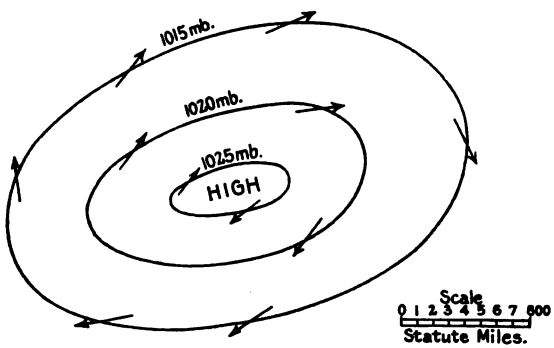


Fig. 60

lighter. The pressure increases towards the centre, round which the air moves in a clockwise direction in the N. Hemisphere, and in an anti-clockwise direction in the S. Hemisphere.

An anticyclone often covers a very large area and moves slowly and irregularly. It may be stationary for weeks together.

Weather usually bright and fine, though cloud sheets may form, and fog is always forecasted in autumn. Rain is never persistent.

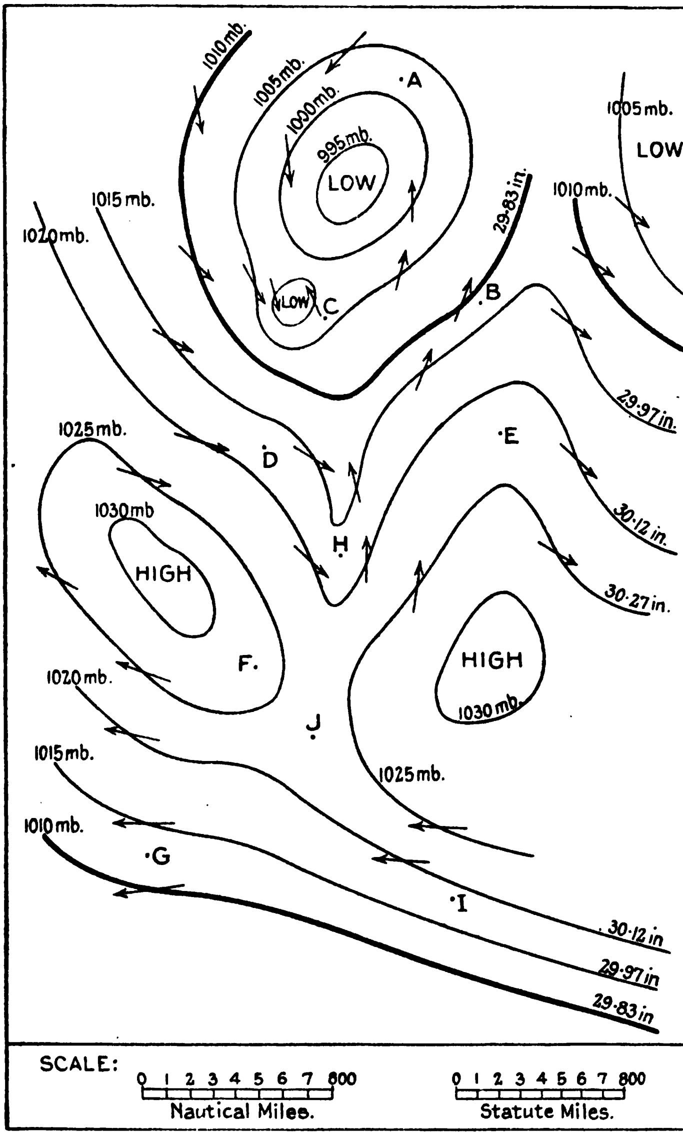


Fig. 61. Sketch showing various depressions

Fig. 61 shows various forms of isobars; the remarks refer to the regions of the British Isles.

A is in a region of cyclonic depression or a **low**.

At the passage of the line of trough severe squalls may occur, with the wind changing suddenly to W.S.W., W., or N.W., the observer being generally South of the centre of the cyclone.

F, G are in an Anticyclone or a **high**.

B, E are in a **wedge** (extension of a high, or thrust between two lows). Rarely accompanied by high winds.

The weather clears up very quickly after the passage of the first low, the wind backs rapidly as the wedge passes, and the weather again changes as the new low approaches. The popular method of expression is "It has cleared up too quickly to last."

C is in a **secondary depression** where there is a small centre of low pressure round which the wind partially circles. The characteristic weather is heavy rain. Thunderstorms often occur in the northern part in hot weather if the secondary depression is a shallow one.

D, H are in a **V-shaped depression** (development of a secondary, or thrust between two highs).

The sequence of weather is generally blue sky, halo, cloud, and later on rain with falling barometer and S. to S.W. wind; at the passage of the trough a line squall may occur, the wind shifting suddenly to N.W.: the sky rapidly clears as the barometer rises.

Note. By the time the secondary depression in the figure (near C) has developed into the V-shaped depression, the cyclone to the north will probably have disappeared.

I is in a region of **straight isobars**; light showers may occur, and the wind is often strong or gusty.

J is in a region between two highs, called a **col** (or neck).

Since there is no gradient, there is a comparative calm but the wind blows in various directions. Dull, gloomy and stagnant. In summer violent thunderstorms are frequently found. No sequence of weather can be assigned to a col.

Examples 29

Give the approximate velocity of the gradient wind, both in m.p.h. and knots, at the places A, B, C, D, E, F, G, H, I, J, in Fig. 61, and any remarks about dangerous conditions.

Movement of Depressions

In these latitudes, it is found that "Lows," "Secondaries," "V's," and "Wedges," move in a more or less easterly direction, the average rate being roughly 20 m.p.h.

Forecasting Fog

When the following conditions exist, fog or mist is frequently to be expected:—

(1) Clear sky, allowing heat to radiate freely.

(2) Wind not more than 5 m.p.h.

(3) Air nearly saturated; difference of wet and dry bulb thermometer not more than 1°.

The best time for observations is about 8 p.m.

If conditions (1) and (2) exist, then, if (3) holds, it is an indication that fog will form almost immediately.

If (3) does not hold, the wet and dry bulb thermometer should be carefully watched to see when the difference approaches 1°.

APPENDIX OF EXAMPLES

A_1. (*Map*)

(1) An aeroplane is flying by the compass mark 5, and finds that Peterborough bears 210° (comp.) and Wisbech bears 100° (comp.). Find the magnetic bearing and distance of Grantham.

(2) From an airship Nottingham is observed to be in line with Derby and Grantham bears S. (mag), the compass course being 205°. How far is she from Northampton?

(3) An airship, compass course 35°, notices that Peterborough is right ahead and the angle from the nose to Cambridge is 60°. How far off Peterborough is she?

(4) An aeroplane leaves Cranwell, her compass course being 172°, and shortly after, observes that the angle from the nose to Peterborough is 24° and to Wisbech is 303°. Mark her position at the time of observation, and give the desired track angle and distance to Cambridge.

A_2. (*Chart*)

(1) From a seaplane, flying by compass mark 30, Kentish Knock Lt. bore 320° and N. Foreland 240°, both by compass. Find the latitude and longitude, and the distance from Sheerness.

(2) You found that Cross Sands Lt. was in line with Yarmouth, and Smith's Knoll Lightship bore N. by compass. The compass course at the time was 270°. Find your latitude and longitude, and your distance from Lowestoft.

(3) A seaplane is flying by compass mark 30 when the N. Hinder Lightship is dead astern and the angle from the nose to the Shipwash Lt. is 50°. How far is she from Orford?

(4) A seaplane leaves Ramsgate for Nieuport, compass course 140°. After 20 minutes the angle from the nose to the West Hinder Lightship was 253° and to the Middlekercke Lt. was 308°. How much longer will the seaplane take to reach Nieuport?

B_1

Find the speed and direction (mag) of the wind in the following cases:—

(1) Course 83° (mag); air speed 70 m.p.h.; observed track angle 120° (mag), observed ground speed 55 m.p.h.

(2) When the air speed was 55 m.p.h. and the course 287° (mag), the observed track angle and ground speed were found to be 308° (mag) and 49 m.p.h.

(3) Compass course S.; air speed 80 m.p.h.; observed track angle 153° (mag), observed ground speed 65 m.p.h.

(4) A 60 m.p.h. machine steering 135° (comp.) observes her track angle to be 110° (mag), the observed ground speed being 50 m.p.h.

(5) Steering on the compass mark 8, air speed 70 m.p.h., it is observed that the track angle is 65° (mag), and the ground speed is 31 m.p.h.

(6)* At 10.50 a.m. an aeroplane is over Peterborough, the compass course being 232° and air speed 80 m.p.h. At 11.10 a.m. she is over Bedford.

(7)* Leaving Coventry at 2 p.m. steering by the compass mark 11, air speed 90 m.p.h., you are over Northampton at 2.17 p.m.

(8)* At 3 p.m. Wisbech bore by compass 125° and Peterborough 218°, the compass course at the time being 295°. Air speed 60 m.p.h. At 3.30 p.m. the machine was directly over Grantham.

(9)* After flying 224° by compass from Boston for half an hour, air speed 70 m.p.h., it was found that Leicester bore 316° (comp.), and Northampton 217° (comp.).

(10)* Left Oxford at 1 p.m. flying 52° (comp.), air speed 67 m.p.h. At 2 p.m. Bedford bore 228° (comp.), and Cambridge 139° (comp.).

(11)* Flying 156° (comp.) at an air speed of 63 m.p.h. an aeroplane was over Nottingham at 4.40 p.m.
At 5.20 p.m. Peterborough bore 293° (comp.) and Wisbech 41° (comp.).

(12)* At 3 p.m. you are over Reading, the compass course being 20° and the air speed 65 m.p.h.
At 4 p.m. the angle from the nose to Bedford is 298° and to Cambridge is 36°.

* On Map.

B_2. (*Chart*)

Find the speed and direction (true) of the wind in the following cases:—

(1) A seaplane leaves Harwich at 3 p.m. steering by compass mark 10, air speed 74 knots, and is over Shipwash Lt. at 3.15 p.m.

(2) At 10 p.m. you were over Sheerness, compass course 70°. At 10.25 p.m. you were over the Kentish Knock Lt. Air speed 86 knots.

(3) An airship, air speed 50 knots, is over Smith's Knoll Lt. at 12 noon, compass course 279°. She reaches Cromer at 12.43 p.m.

(4) At 3 p.m. you are over the N. Hinder Lightship flying W. by compass. Air speed 82 knots. At 3.30 p.m. Shipwash Lt. was 55° from the nose of the machine and Kentish Knock Lt. 334°.

(5) Flying from Southwold by compass mark 12, air speed 88 knots, a seaplane found after 20 minutes that the N. Hinder Lightship was ahead and Shipwash Lt. bore 237° by compass.

(6) You leave Lowestoft in a 72 knot machine at 8.15 p.m. Compass course S. At 8.38 p.m. you observe that the N. Hinder Lightship bears 112° and Shipwash Lt. 238°, both by compass. Mark the N.D. position at 8.38 p.m. and find the actual direction and speed of the wind.

C_1

(Estimated Position, etc.)

(1) The wind is estimated to be from 160° (mag) at 30 m.p.h.: find the estimated track angle and ground speed, when the course is 120° (mag) and the air speed 70 m.p.h.

(2) The course is 317° (comp.); air speed 80 m.p.h. and the wind estimated at 30 m.p.h. from N. (mag). Find the estimated track angle, ground speed, and angular drift.

(3) Find the estimated ground speed and angular drift when the course is 167° by compass, the air speed 80 m.p.h. and the wind is estimated to be 40 m.p.h. from 135° (mag).

(4) The air speed is 71 m.p.h. and the wind is estimated to be from 30° (true) at 44 m.p.h. Find the estimated angular drift and ground speed when the course is 73° (mag). Variation 10° E.

(5)* At noon an aeroplane was directly over Northampton flying by the compass mark 12; air speed 80 m.p.h., the wind being estimated to be from S. (true) at 30 m.p.h. Mark the estimated position at 12.30 p.m. and give the estimated distance from Cambridge.

(6)* At 1 p.m. you are directly over Northampton, compass course 40°, estimated wind 20 m.p.h. from 300° (true), air speed 60 m.p.h. Mark the N.D. and estimated positions at 1.30 p.m. If at this time you find you are directly over Peterborough, find the actual speed and direction of the wind.

(7)* Left Peterborough at noon flying by the compass mark 26, air speed 82 m.p.h., estimated wind 30 m.p.h. from 195° (mag). Mark the N.D. and estimated positions at 12.15 p.m. If at 12.30 p.m. you observe you are right over Leicester, what was the actual direction and speed of the wind?

(8)* At noon an aeroplane was flying 90° (comp.) and observed Derby to bear 300° (comp.) and Nottingham 30° (comp.). Her air speed was 70 m.p.h. and the wind was estimated at 30 m.p.h. from 340° (true). Mark the estimated position at 12.30 p.m. and if at this time the aeroplane was over Cranwell, find the actual speed and direction of the wind.

(9)* From a 70 m.p.h. machine, flying 240° (comp.), Wisbech bore 35° (comp.) and Peterborough 290° (comp.) at 2 p.m. If the wind is estimated at 30 m.p.h. from 120° (true), mark the estimated and N.D. positions at 2.30 p.m. At 2.30 p.m. you find you are right above Northampton. Correct your estimate of the wind.

C_2. (*Chart*)

(1) At 2 p.m. a seaplane left Ramsgate flying by compass mark 6. Air speed 76 knots. Mark the N.D. position at 2.35 p.m. The estimated wind was from 300° (true) at 30 knots. Give the estimated position (lat. and long.) and also the ground speed.

(2) At 1 p.m. you are over Dunkerque, compass course 322°. Air speed 72 knots. Estimated wind from 220° (true), 27 knots. Give the estimated position at 1.40 p.m. At this time Harwich is observed ahead, and Kentish Knock Lt. is 270° from the nose of the machine; find the actual speed and direction of the wind.

(3) You are over the Varne Lt. in an 80 knot machine, compass course 87°. At 2.40 p.m. Dunkerque bore 140°, and the West Hinder Lt. 65°, both by compass. Estimated wind was from 85° (true), 32 knots. Find the actual direction and speed of the wind, and find your estimated position at 3.15 p.m.

* On Map.

(4) A seaplane flying S. by compass, air speed 70 knots, leaves Harwich at 5 p.m. Estimated wind from 225° (true), 30 knots. Mark the estimated position at 5.20 p.m. At this time the seaplane is over Kentish Knock Lt. and continues her course until 5.45 p.m., when she finds herself over a submarine. Give the actual speed and direction of the wind, and the latitude and longitude of the submarine.

(5) A seaplane leaves Wells at 2 p.m., compass course 145°. Estimated wind from 220° (true), 18 knots. Air speed 58 knots. Give the latitude and longitude of your estimated position at 2.50 p.m. At this time the seaplane is over Cross Sands Lt. and continues her course. At 3.10 p.m. she is over a submarine. Find the actual speed and direction of the wind and the latitude and longitude of the submarine.

D_1. (*Map*)

(Allowance for wind in finding the course)

(1) Leaving Bedford for Leicester with a 20 m.p.h. wind dead against you and an air speed of 74 m.p.h., what will be the compass course, and when will you arrive at Leicester?

(2) How long will it take an aeroplane, air speed 94 m.p.h., to get from Wisbech to Bedford with the wind right behind her, and what will be the compass course? Speed of the wind 30 m.p.h. Allow five minutes for climbing to the required height.

(3) Find the compass course and the time taken, working either on the map or on paper.

	Desired track angle and distance	Estimated wind	Air speed
(*a*)	80° (mag), 120 miles	from 220° (mag), 40 m.p.h.	60 m.p.h.
(*b*)	55° (mag), 42 miles	from E. (mag), 40 m.p.h.	80 m.p.h.
(*c*)	320° (mag), 50 miles	from W. (mag), 20 m.p.h.	62 m.p.h.
(*d*)	350° (mag), 184 miles	from 25° (mag), 34 m.p.h.	92 m.p.h.

(4) Find the compass course and the time taken.

	From above	To	Estimated wind	Air speed in m.p.h.
(*a*)	Nottingham	Cambridge	from 51° (mag), 35 m.p.h.	80
(*b*)	Cambridge	Nottingham	from 51° (mag), 35 m.p.h.	80
(*c*)	Reading	Cranwell	from 340° (true), 25 m.p.h.	75
(*d*)	Cranwell	Reading	from 340° (true), 25 m.p.h.	75

(5) Find the course to steer when flying from Boston to Bedford, air speed 55 m.p.h. Wind from 225° (true), 20 m.p.h.

(6) What compass course should be steered from Northampton to Nottingham, when the air speed is 72 m.p.h. and the wind is from 130° (true) at 40 m.p.h., and how long will it take?

(7) If an aeroplane is over Greenwich at 1 p.m., the air speed being 80 m.p.h. and the wind 30 m.p.h. from 80° (true), when would you expect to arrive at Coventry, and what will be the compass course?

(8) You have to fly from Nottingham to Boston, air speed 112 m.p.h., wind 35 m.p.h. from 50° (mag); find the compass course and the time taken, allowing five minutes for climbing.

(9) Find the course (mag) and the estimated ground speed to fly from Northampton to Boston, your air speed being 106 m.p.h. and the wind estimated to be from 110° (true) at 40 m.p.h.

(10) With the wind blowing from S.W. (true) at 30 m.p.h., how will you steer by compass and how long will you take to reach a point which is S. (true) of you, distant 110 miles, your air speed being 60 m.p.h.? Variation 15° W.

(11) If scouting from Coventry to Cambridge with the wind from 150° (true) at 30 m.p.h., and air speed 70 m.p.h., what would be your compass course and ground speed?

(12) At 4 p.m. you are over Cambridge, your air speed is 80 m.p.h. and the wind is estimated at 35 m.p.h. from 50° (mag). Can you get to Coventry in an hour?

(13) The course at 3 p.m. was 250°, Nottingham bore 310° and Grantham bore 63°, all by compass; the estimated wind was from 260° (true), 40 m.p.h., and the air speed 80 m.p.h. Find the compass course and time to Bedford.

Find also the compass course and time taken to return from Bedford to Nottingham.

(14) You are told to fly from Reading to Cambridge, then to Northampton and return to Reading. The wind is estimated at 35 m.p.h. from 0° (true). If your air speed is 84 m.p.h. find how long it will take you, allowing four minutes for the climb.

D_2. (*Chart*)

(1) Find the compass course and time taken, to fly

	From	To	Estimated wind	Air speed
(*a*)	Ramsgate	Dunkerque	from 225° (true), 30 knots	60 knots
(*b*)	Harwich	Zeebrugge	from 280° (mag), 20 knots	70 knots
(*c*)	Sheerness	Lowestoft	from 50° (mag), 25 knots	68 knots
(*d*)	Dungeness	Ostend	from 130° (true), 28 knots	72 knots

(2) You fly from above Harwich to Dunkerque, air speed 74 knots. Estimated wind from S. (mag) 20 knots. Find your compass course and the time when you would expect to pass the Kentish Knock Lt.

(3) A seaplane is ordered to scout from Cross Sands Lt. to Shipwash Lt. and return. Air speed 68 knots. Wind from 300° (mag), 24 knots. Find the compass courses out and back, and the total time taken for the patrol.

(4) You are ordered to patrol in the direction of Shipwash Lt. from Sheerness in a 72 knot machine. Estimated wind from 310° (true), 18 knots. Find your compass course and the time when you would expect to be over Shipwash Lt.

(5) Ordered to patrol from Sheerness to Shipwash Lt. and then to the N. Hinder Lt., returning to Sheerness. Air speed 72 knots. Estimated wind from 310° (true), 18 knots. Find the compass courses at Sheerness, the Shipwash Lt. and the N. Hinder Lt. and also the total time taken for the patrol.

(6) At 2 p.m. Smith's Knoll Lt. bore N. by compass and Cross Sands Lt. 280° when the compass course was 220°. Estimated wind from 150° (true), 18 knots. Air speed 64 knots. How much must the course be altered to reach Harwich, and which way? Also how long will it take to reach Harwich?

(7) A submarine is reported to be aground in 51° 49′ N., 1° 25′ E. You fly from Sheerness in a 72 knot machine to this position. Estimated wind from 320° (mag), 34 knots. Find your compass course and the time taken to reach the submarine.

If you found yourself over the submarine after 35 mins., what would have been the actual direction and speed of the wind?

(8) A ship signals that she is being attacked by a submarine in 52° 50′ N., 2° 5′ E. You leave Southwold in a 68 knot machine for this position. Estimated wind from 130° (true) at 18 knots. Find the compass course and the time taken to arrive at the position reported, allowing five minutes for climbing.

E_1

(Correction of course for drift)

(1) To proceed in the direction 252° (mag), the course by compass, allowing for wind, was found to be 270°. What is the estimated angular drift?

(2) When the desired track angle was 8° (mag), the course, allowing for wind, was found to be 355° (comp.). What was the estimated angular drift?

(3) When steering 35° (comp.), it was found by observation that the actual track angle was 40° (mag). What was the observed angular drift?

(4) The compass course being 5°, observation showed that the actual direction in which the aeroplane was proceeding was 350° (mag). What was the observed angular drift?

(5)* Flying from Oxford to Peterborough, the compass course, allowing for wind, was found to be 69°. Observation however showed that the track was in the direction of Northampton. What should your new course be?

(6)* Allowing for wind, the compass course from Bedford to Grantham was found to be 4°. It was found however by observation that the track was in the direction of Cranwell. How much should the course be altered, and which way? State the new compass course.

(7) Find the amount you should alter course in the following cases; state in each case whether to the right or left, and give the new compass course.

	Compass Course	Estimated Angular drift	Angular drift (by observation)	Direction of wind (mag)
(a)	195°	20°	25°	from 120°
(b)	130°	15°	12°	from 200°
(c)	6°	10°	20°	from 30°
(d)	0°	24°	18°	from 270°
(e)	208°	6°	10°	from 160°
(f)	50°	30°	25°	from 140°
(g)	340°	22°	28°	from 40°

* On Map.

E_2. (*Chart*)

(1) Allowing for an estimated wind, the compass course from Lowestoft to Calais was found to be 181°. It was found however that the track was in the direction of Southwold. How much should the course be altered, and which way? State the new compass course.

(2) Allowing for an estimated wind, the compass course from Sheerness to Dunkerque was 135°. It was found that the track was in the direction of North Foreland. How much should the course be altered, and which way? State the new compass course.

(3) Allowing for an estimated wind, the compass course from Lowestoft to North Foreland was 189°. It was found however that the track was in the direction of Southwold. How much should the course be altered, and which way? State the new compass course.

F_1

(Joining up with a squadron, etc.)

(1) An aeroplane, air speed 60 m.p.h., is ordered to join a squadron which is leaving an aerodrome bearing 160° (mag), distant 62 miles, and which is flying 90° (mag) at 40 m.p.h. Find the compass course to steer and the time taken.

(2) A Zeppelin is reported to be over a place which bears 130° (mag), distant 80 miles. She is estimated to be flying N. (mag) at an air speed of 60 m.p.h. How should an aeroplane, air speed 70 m.p.h., steer to intercept her, and how long will she take?

(3) Find the compass course necessary to intercept a hostile airship which is reported directly overhead from a place 96° (mag), 120 miles from you. The enemy is estimated to be steering 236° (mag) at 40 m.p.h. Your own air speed is 60 m.p.h. Find also the time taken to intercept him, allowing four minutes for climbing.

(4) A squadron is reported bearing 20° (mag), 50 miles away from you, and flying 90° (mag), at an air speed of 70 m.p.h. Find your compass course in order to join the squadron, and the time you would take, your own air speed being 85 m.p.h.

(5) Find the compass course and time taken to intercept a squadron which is flying 330° (mag), air speed 80 m.p.h., your own air speed being 70 m.p.h. The squadron is 100 miles away, bearing 120° (mag).

(6) Your air speed is 76 m.p.h., how soon can you intercept a squadron which is 64 miles distant and bearing 100° (mag) from you, and flying 225° (mag) at 82 m.p.h.? State also your compass course.

(7)* An aeroplane, air speed 65 m.p.h., is over Peterborough. Find the compass course and time taken to join up with a squadron which is over Derby, steering 170° (mag) at an air speed of 70 m.p.h.

(8)* A squadron is over Oxford, course 32° (mag), air speed 80 m.p.h. Find the compass course and time taken for an aeroplane, air speed 65 m.p.h., to join up, if she is over Cambridge at the time.

(9)* At 9 a.m. a squadron is over Leicester, and an aeroplane over Peterborough is ordered to join up as soon as possible. Course of squadron 70° (mag); air speed of squadron 90 m.p.h.; air speed of aeroplane 64 m.p.h. Find the requisite compass course and the time when the aeroplane will join.

(10)* A squadron, with an air speed of 72 m.p.h., is flying 170° (mag) over Nottingham when you start from above Oxford to join it. Find the compass course and time taken, if your air speed is 70 m.p.h.

(11)* You leave Oxford at 10.20 a.m. (air speed 80 m.p.h.) to join up with a squadron which was over Boston at 10 a.m. steering 265° (mag) at an air speed of 70 m.p.h. Find your compass course and when you would expect to join; allow six minutes for climbing.

(12)* A squadron is reported over Coventry at 2 p.m. and over Leicester at 2.18 p.m. on a day when there was no wind. Find the compass course that an aeroplane should steer to join up, if she starts from Peterborough at 2.30 p.m., her air speed being 80 m.p.h., and the time when she will join, allowing six minutes for climbing.

F_2. (*Chart*)

(1) Find the compass course and the time taken in each case for the seaplane to join up with the squadron.

	Bearing and distance of squadron	Air speed of squadron (knots)	Course (mag) of squadron	Air speed of seaplane (knots)
(*a*)	130° (mag); 60′	75	10°	80
(*b*)	340° (mag); 44′	65	35°	100
(*c*)	250° (mag); 100′	80	120°	80
(*d*)	42° (mag); 75′	70	190°	60
(*e*)	160° (mag); 80′	75	260°	90

* On Map.

(2) A squadron is over Sheerness, course 100° (mag), air speed 72 knots. Find the compass course for a seaplane to join the squadron from Harwich. Air speed 75 knots. Find also the time taken.

(3) You are ordered to join a squadron which is over Harwich steering 140° (mag), air speed 68 knots. You start from Lowestoft in an 80 knot machine. Find your compass course and the time you would expect to take to join the squadron, allowing three minutes for climbing.

(4) An airship, air speed 50 knots, is over Smith's Knoll Lt. steering 300° (mag). A seaplane is ordered to join her from Lowestoft, air speed 55 knots. Find the compass course and time taken, allowing two minutes for climbing.

(5) At 9 a.m. a squadron is over Colchester, magnetic course 110°, air speed 62 knots. You are ordered to join this squadron from Deal, air speed 60 knots. Find the requisite compass course and the time you would expect to join. Climbing time, five minutes.

(6) A squadron was over Sheerness at 2.15 p.m. and reported over North Foreland at 2.40 p.m. on a day when there was no wind. At 2.40 p.m. a seaplane, 75 knots, proceeds from above Orford to join this squadron. Find the requisite compass course and the time of joining up.

G_1

(Intercepting an enemy, given his observed track and ground speed)

(1) Enemy aeroplane is reported 20 miles, 13° (mag) of you, his observed track angle being 103° (mag) and ground speed 60 m.p.h., the wind is from 150° (true) at 18 m.p.h. Your own air speed is 80 m.p.h. Find your compass course, and time taken to intercept him. Variation 13° W.

(2) Your air speed is 82 m.p.h. and the wind is estimated to be from 90° (mag) at 25 m.p.h. Find your compass course and the time taken to intercept a hostile aeroplane which is 190° (mag) 15 miles distant, his observed track angle being given as 110° (mag), and ground speed 50 m.p.h.

(3) The track angle and ground speed of the enemy are signalled as 225° (mag), 55 m.p.h., and his bearing and distance are 315° (mag) 20 miles. You estimate the wind at 25 m.p.h. from 240° (mag). What compass course should you steer and how long should you take to intercept him if your own air speed is 90 m.p.h.?

(4)* An enemy airship is reported to be over Reading at 7 p.m. and over Greenwich at 8 p.m. You are 15 miles, 351° (mag) from Greenwich at 8 p.m. and have an air speed of 90 m.p.h. The wind is estimated to be from 215° (mag) at 20 m.p.h. What compass course should you steer to intercept him and when would you expect to come up with him, if it takes you four minutes to climb?

(5)* An enemy airship is reported to be over Wisbech at 8.40 p.m. and over Peterborough at 9 p.m. If at 9 p.m. you are at Cambridge, what should be your compass course to intercept the airship, and when would you expect to be within 5 miles of it? Your own air speed is 84 m.p.h. and the wind is estimated to be from 0° (mag) at 10 m.p.h. Allow three minutes to climb.

G_2. (*Chart*)

(1) A Zeppelin is reported over Cromer at 10 p.m., her observed track angle being 120° (mag) and ground speed 40 knots. The wind is from 50° (true), 32 knots. What should be the compass course a seaplane should steer to intercept it, if she is over Yarmouth at 10 p.m. and her air speed is 70 knots, and when would she expect to come up with the Zeppelin?

(2) An airship is 15 miles E. (mag) of the Shipwash Lt. at 6 a.m., travelling N.E. (true) at 30 knots. A seaplane leaves Harwich at 6.30 a.m. to join her, the air speed being 80 knots, and the wind 15 knots from 150° (true). Find the compass course to steer and the time of joining, allowing ten minutes for climbing.

(3) A hostile airship is reported to be over Ostend at 8 p.m., her track angle being estimated at 300° (mag) and ground speed 60 knots. Wind is from 60° (mag) at 30 m.p.h. A squadron leaves Dunkerque at 8.10 p.m. to intercept her, air speed 90 knots. What should be the magnetic course, and when should the squadron come up with the airship? Allow eight minutes for climbing.

(4) A Zeppelin is reported over Norwich at 9 p.m. and over Lowestoft at 9.30 p.m. A seaplane leaves Ipswich at 9.30 p.m., air speed 90 knots, wind N.E. (true) 20 knots. What compass course should she steer to intercept her, and when should she expect to come up with her if the plane takes ten minutes to climb to the required height?

(5) Enemy is reported over N. Foreland at 9 p.m. and over Kentish Knock Lt. at 9.15 p.m. Find the compass course and time taken for a 90 knot machine to intercept him, leaving Harwich at 9.20 p.m. Wind from 120° (mag) at 25 m.p.h.

* On Map.

H_1

(Scouting Range, returning to same base)

(1) Scouting at an air speed of 80 m.p.h., with a wind of 25 m.p.h. dead against you on the outward journey and with you on the return, after what time should you turn to be back again in 3 hours, and how far will you get?

(2) If your air speed is 92 m.p.h. how far can you scout with the wind 30 m.p.h., and be back in 4 hours, assuming that the wind will be dead against you on the return, and after what time should you turn?

(3) Find when you should turn if scouting in the direction 110° (mag) with a 20 m.p.h. wind from 110° (mag); air speed 83 m.p.h. You are to be back in $3\frac{1}{2}$ hours.

(4) An aeroplane leaves her base at 8 p.m. to scout in the direction 30° (mag); her air speed is 105 m.p.h. and the wind is from 210° (mag) at 30 m.p.h. If she is to be back by midnight, find when she should turn, and her scouting range.

(5) The wind is 35 m.p.h. from 10° (mag) and the air speed 70 m.p.h. If you are ordered to scout 80° (mag) and return in 5 hours, find when you should turn, and your scouting range.

(6) After what time should an aeroplane turn, when ordered to scout in the direction 310° (mag) and return in 5 hours; air speed 60 m.p.h.; wind is 40 m.p.h. from 315° (mag)? How far will she get away from her base?

(7) If ordered to scout in the direction 180° (mag) and return in 3 hours, your air speed being 72 m.p.h., find the time to turn in the following cases:—

(*a*) When there is no wind.

(*b*) When the wind is from 180° (mag) at 30 m.p.h.

(*c*) When the wind is from 0° (mag) at 30 m.p.h.

(8) How far can you scout in the direction 300° (mag) when the wind is 30 m.p.h. from 180° (mag) and be back to your base in 4 hours if your air speed is 60 m.p.h.? When should you turn back?

(9) You are ordered to go W. (mag) as far as you can, and be back in 2 hours. The wind is estimated to be from 130° (mag) at 25 m.p.h. and your air speed is 80 m.p.h. When should you turn?

(10) If scouting in the direction 100° (mag) and returning to your base in 4 hours, your air speed being 92 m.p.h., how much farther can you scout if the wind is from 190° (mag) than if it is from 100° (mag), the speed of the wind being 45 m.p.h.?

(11) The wind is from 0° (mag) at 50 m.p.h., your air speed is 105 m.p.h., and you are to be back in 3 hours.

Find the times to turn if you scout in the directions

(*a*) 0° (mag), (*b*) 180° (mag), (*c*) 90° (mag).

Give the scouting range in each case.

(12) The wind is from 60° (mag) at 30 m.p.h. How far can an airship, air speed 50 m.p.h., scout in the following directions, returning to her base in 8 hours:—

(*a*) 230° (mag), (*b*) 50° (mag), (*c*) 140° (mag)?

State also in each case after what time she should turn.

(13) The wind is estimated at 45 m.p.h. from 120° (mag); if your air speed is 95 m.p.h., state the direction of scouting in which your range would be (*a*) the greatest, (*b*) the least, and give the values in these cases for a 2½ hours' flight.

(14)* After what time should you turn if scouting from Cambridge to Nottingham, if you are to be back in 4 hours; air speed 80 m.p.h., wind 35 m.p.h. from 50° (mag)? What is your scouting range and your compass course out?

(15)* In scouting from Cranwell to Reading with orders to be back in 3 hours, when should you turn if the wind is 25 m.p.h. from 340° (true), your air speed being 75 m.p.h.? Give also the compass courses out and home and the scouting range.

(16)* You leave Northampton at 1 p.m. with orders to scout in the direction 70° (mag) and to be back by 2 p.m. Air speed 75 m.p.h. Wind 30 m.p.h. from 120° (true). When must you turn and how far can you get from Northampton?

What are your compass courses out and home?

(17)* An aeroplane is ordered to scout along a line 45° (mag) from Oxford and to be back in 2 hours; her air speed is 100 m.p.h. and there is a 40 m.p.h. wind from 70° (true). Find the compass courses out and home, the time when she should turn and the scouting range.

(18)* Your air speed is 65 m.p.h. and the wind is from 345° (true), 30 m.p.h. If you leave Derby at 7 p.m. with orders to scout 135° (mag) and be back in 2½ hours, state when you should turn, and give the compass courses out and home, and the scouting range.

* On Map.

H_2. (*Chart*)

(1) Find the compass courses out and home, the time to turn, and the scouting range in the following cases, allowing 1 hour margin of safety in the time of flight:—

	Direction of scouting (mag)	Air speed (knots)	Estimated wind	Variation	Petrol supply for
(*a*)	55°	80	from 105° (true); 40 knots	15° W.	7 hours
(*b*)	130°	70	from 170° (mag); 40 knots	10° E.	6 hours
(*c*)	190°	60	from S.W. (true); 30 knots	10° W.	5 hours
(*d*)	285°	80	from 345° (mag); 30 knots	15° E.	7 hours

(2) At 11 a.m. a seaplane is ordered to scout from Yarmouth in the direction E. (mag), and be back by 1 p.m. Her air speed is 70 knots and the wind is from 330° (mag), 30 knots. Find when she should turn, and give her compass courses out and in and the latitude and longitude of her position when she turns.

(3) After what time should a seaplane turn if ordered to scout E. (mag) from Lowestoft and be back in 2 hours. Air speed 80 m.p.h. and wind from E. (true) 28 m.p.h. State also the compass courses out and home and the latitude and longitude of her turning point.

(4) An 80 knot seaplane leaves Southwold at 4 p.m. to scout towards the position 52° N., 3° E., and be back in 2 hours. The wind is from 325° (mag) at 25 knots. State her compass courses out and home, the time when she should turn, and the scouting range.

(5) A 90 knot machine leaves N. Foreland to scout as far as possible towards Zeebrugge and be back in 1½ hours. Wind is 40 knots from 195° (true). Find when she should turn and how far she is off Zeebrugge when she turns.

(6) A machine starts from Calais at 4 a.m. and is ordered to go as far as possible in the direction of W. Hinder Lt. and be back in 4 hours. Her air speed is 100 knots and the wind is from 293° (mag), 18 knots. How far can she go before turning, and when should she be over the W. Hinder Lt. (*a*) on the outward, (*b*) on the return journey?

I_1

(Scouting Range, returning to a different base)

(1) An aeroplane, air speed 70 m.p.h., is ordered to scout in the direction 45° (mag), and return in 4 hours to a place which is 10° (mag), distance 100 miles from her starting place. The wind is from 270° (mag) at 20 m.p.h. Find the courses (mag) out and home, the time to turn and the scouting range.

(2) How far can you scout in the direction 315° (mag), and return in 3 hours to a place bearing 0° (mag), 90 miles from your starting place? Air speed 60 m.p.h.; wind from N. (true) at 20 m.p.h. Variation 15° W. Give also the compass courses on the outward and return journeys, and the time to turn.

(3) An aeroplane leaves a place A, at 2 p.m., to scout in the direction 135° (mag) and return to another place B in 5 hours.

B is 210° (mag) 80 miles from A; air speed 65 m.p.h.; wind from 285° (mag) at 25 m.p.h.

Find when she should turn, and give the compass courses out and home, and the scouting range.

(4)* You are ordered to scout from Kingston in the direction of Wisbech, and to be at Nottingham in 2½ hours. The wind is from 270° (true) at 15 m.p.h. and your air speed is 60 m.p.h. Find the compass courses out and in, and the time to turn. How far from Wisbech would you be when you turn?

(5)* The wind is from 90° (mag) at 20 m.p.h.; how far towards Oxford can an aeroplane scout from Greenwich and arrive at Leicester in 2 hours, when her air speed is 50 m.p.h.? Give also the compass courses out and back, and the time to turn.

(6)* Find the distance you can scout from Leicester towards Cambridge returning to Cranwell in 3 hours. Air speed 50 m.p.h. and wind from N. (true) at 20 m.p.h.

Give also the compass courses out and in, and the time to turn.

(7)* How far can you proceed from Bedford towards Derby and return to Grantham in 2½ hours, the wind being from 100° (mag) at 30 m.p.h. and your air speed 55 m.p.h.?

Give also the compass courses out and in, and the time to turn.

* On Map.

I_2. (*Chart*)

(1) A seaplane leaves Lowestoft with orders to scout as far as possible towards Zeebrugge and return to Dover in 3 hours. Air speed 55 knots. Wind 15 knots from N. (true).

Give the compass courses out and in, the time to turn, and the scouting range.

(2) How far from Calais can a seaplane scout in the direction over N. Hinder Lt. and return to Harwich in 3 hours? Air speed 52 knots. Wind from E. (mag) at 10 knots.

Give the compass courses out and in, and state when she would be over the N. Hinder Lt., if she leaves Calais at 3 p.m.

(3) A fleet leaves Calais at 10 a.m., steaming N. (mag) at 20 knots, at the same time as a seaplane, air speed 70 knots. The seaplane is to scout as far as possible in the direction 50° (mag) returning to the fleet by 1 p.m. The wind is from 270° (mag), 25 knots.

Find the compass courses out and back to the fleet, the time to turn, and the scouting range.

(4) A seaplane, air speed 70 knots, is ordered to scout in the direction 100° (mag), leaving Lowestoft at the same time as a seaplane carrier. The carrier is steaming S. (mag), 20 knots. If the wind is 25 knots from 215° (true) and the seaplane is to rejoin her carrier in 4 hours, find her scouting range, the compass courses out and back, and the time to turn.

(5) An 80 knot machine leaves Dover at 7.30 a.m. with orders to scout in the direction 15° (mag) and to join the fleet at 10 a.m. in lat. 52° 20′ N., long. 3° 20′ E. The wind is from 150° (true) at 20 knots. When should she alter course, and what will be her compass courses and her scouting range?

(6) A fleet leaves Harwich at 8 a.m. steering 120° (mag), 25 knots. At 9 a.m. a seaplane, air speed 60 knots, leaves Harwich to scout in the direction towards Dunkerque, and to pick up the fleet at 11 a.m., the wind being from 45° (true) at 20 knots. Find when she should alter course, her compass courses, and the distance from Dunkerque when she turns.

(7) 9 a.m. Fleet leaves Lowestoft, course 170° (mag), speed 25 knots.

10 a.m. An aeroplane leaves Dunkerque with orders to scout 60° (mag), air speed 80 m.p.h., and pick up the fleet at 11 a.m. If the wind is 20 knots from 135° (mag), find when she should alter course, and her scouting range.

J_1. (*Map*)

(1)

4.15 p.m. An aeroplane is over Boston, steering 220° by compass, air speed 100 m.p.h.
Mark the N.D. position at 4.55 p.m.

4.55 p.m. Leicester bore N. (comp.) and Coventry bore 280° (comp.).
Mark the observed position at 4.55 p.m. and find the observed values of the speed and direction of the wind, the angular drift, and the ground speed.

4.55 p.m. Ordered to return to Boston.
Find the compass course, allowing for the wind: give the estimated ground speed and time of arrival. State how close to Leicester you would expect to pass on your way back.

(2)

7.20 p.m. Above Leicester, steering by the compass mark 14, air speed 80 m.p.h.
Mark your N.D. position at 7.55 p.m.

7.55 p.m. Northampton bore 330° (comp.) and Bedford 45° (comp.).
Fix your position and find the direction and speed of the wind, and find the compass course to Leicester.

8.0 p.m. Altered course, as already found, for Leicester.
When would you expect to arrive?

(3)

8.0 p.m. Over Cranwell, compass course 209°, air speed 66 m.p.h.

8.10 p.m. Over Grantham.
Mark the N.D. position at 8.10 p.m. and find the direction and speed of the wind.
Altered course for Reading, allowing for wind.
Give the compass course and estimated ground speed, and state how near to Northampton you would expect to pass.

9.10 p.m. Northampton bears 232° (comp.) and Bedford 161° (comp.).
Mark the estimated and observed positions at 9.10 p.m. and make an estimate of the required alteration of course.

9.12 p.m. Altered course for Reading according to previous estimate.
Give this course, mark the estimated position at 10.30 p.m. and state how far you are from Oxford at this time.

(4)

9.0 p.m. Over Kingston, steering straight for Cranwell, the wind at the surface being negligible, air speed 88 m.p.h.
Give the compass course.

9.30 p.m. Bedford was in line with Northampton, and Cambridge bore 76° (comp.).

Mark the N.D. and observed positions at 9.30 *p.m. and find the speed and direction of the wind between* 9.0 *p.m. and* 9.30 *p.m.*

9.40 p.m. Altered course for Grantham, allowing for this estimated wind.

Give the compass course, and state when you would expect to arrive.

10.3 p.m. Peterborough ⏀ Wisbech bearing 84° (comp.).

Find the deviation.

(5)

8.0 p.m. Over Reading, and flew over Oxford to determine the wind, the compass course being 320°, and the air speed 84 m.p.h.

8.20 p.m. Over Oxford.

Mark the N.D. position at 8.20 *p.m., and find the direction and speed of the wind.*

Decided to proceed to Nottingham.

Give the compass course and estimated ground speed, and angular drift.

8.25 p.m. Altered course for Nottingham.

8.40 p.m. Northampton bore 90° (comp.) and Coventry bore 350° (comp.).

Mark the N.D. and observed positions at 8.40 *p.m., find the observed angular drift, and state how much the course should be altered and which way.*

(6)

3.0 a.m. Over Cambridge; course 330° (comp.); air speed 82 m.p.h.

3.20 a.m. Over Peterborough.

Mark the N.D. position at 3.20 *a.m., and find the wind.*

3.25 a.m. Altered course for Leicester, allowing for the wind.

Give the compass course, estimated ground speed and angular drift.

3.40 a.m. Received orders to proceed to Oxford.

Find compass course, and estimated ground speed.

3.45 a.m. Altered course to 211° (comp.).

4.6 a.m. Northampton abeam to port.

Mark the estimated position at 4.6 *a.m., and give the probable time of arrival at Oxford.*

(7)

6.0 p.m. Above Nottingham, air speed 80 m.p.h., wind is estimated at 20 m.p.h. from 45° (true).
Find the compass course to Cambridge and estimated ground speed, and mark the estimated position at 6.45 p.m.

6.45 p.m. Peterborough bore 25° (comp.) and Cambridge bore 115° (comp.).
Mark this observed position, and state the corrected course to Cambridge. When will you expect to arrive at Cambridge?

(8)

10.0 p.m. Above Nottingham, course 145° (comp.), air speed 80 m.p.h.

10.36 p.m. Northampton 275° (comp.) and Bedford 175° (comp.).

10.42 p.m. Altered course to return to Nottingham.
Find the wind between 10 p.m. and 10.36 p.m.; give the requisite course at 10.42 p.m., and the time when you would expect to be back.

J_2. (*Chart*)

(1)

Noon. Over Lowestoft; course 170° (comp.); air speed 65 knots.

12.30 p.m. Shipwash Lt. bore 20° (comp.), Sunk Lt. bore 260° (comp.).
Mark the N.D. and observed positions at 12.30 p.m., find the wind, determine the compass course to Dunkerque, and state the approximate time of arrival.

(2)

9.0 a.m. Over N. Foreland steering 10° (comp.) at 80 knots.

9.50 a.m. Lowestoft 330° (comp.) and Southwold 269° (comp.).
Mark the N.D. and observed positions at 9.50 a.m., find the wind, and determine the compass course to return to N. Foreland.

9.55 a.m. Altered course as previously calculated.
State probable time of arrival at the N. Foreland.

(3)

6.25 a.m. Compass course 40°; air speed 90 knots.
Shipwash Lt. ϕ Sunk Lt. Harwich bore 320° (comp.).
Give the latitude and longitude of the observed position at 6.25 a.m.

7.0 a.m. Over Lowestoft.
Mark the N.D. position, and find the wind.
Ordered to fly to Zeebrugge.
Find the compass course and probable time of arrival.

(4)

10.0 a.m. Left Deal and flew over Kentish Knock Lt. to determine the wind; the compass course was 30°, air speed 65 knots.

10.30 a.m. Over Kentish Knock Lt.
Mark the N.D. position and determine the speed and direction of the wind.

10.45 a.m. Altered course to 70° (comp.).
Find the time when you would expect to be over the N. Hinder light-vessel.

11.25 a.m. You find yourself over a submarine which you proceed to attack.
Give the estimated position of the submarine at 11.25 *a.m.*

11.25 to 11.35 a.m. Courses as requisite.

11.35 a.m. Altered course for Harwich.
Find the necessary compass course, and estimated time of arrival.

(5)

1.0 p.m. Over Lowestoft. Compass course 83°, air speed 68 knots.

1.35 p.m. Smith's Knoll Lt. bore N. and Cross Sands Lt. 280°, both by compass.
Mark the N.D. position at 1.35 *p.m. and give the actual direction and speed of the wind.*

1.40 p.m. Received orders to join a squadron leaving Harwich at 1.45 p.m. flying 100° (mag). Air speed 70 knots.

1.45 p.m. Altered course to join squadron.
Give the estimated position at 1.45 *p.m., also the necessary compass course and expected time of joining the squadron.*

2.40 to 3.0 p.m. Squadron alters course to patrol in the neighbourhood of the N. Hinder Lt. reforming over this light-vessel at 3 p.m.

3.0 p.m. Ordered to return to Lowestoft.
Find the necessary compass course and estimated time of arrival.

(6)

4.0 p.m. You received orders to proceed from Folkestone to the W. Hinder Lt. and thence to scout in the direction of the N. Hinder Lt. Estimated wind from 220° (true), 32 knots. Air speed 68 knots.

4.32 p.m. The W. Hinder Lt. bore N. by compass and the Middlekercke Bank Lt. bore 100° (comp.).
Give the latitude and longitude of the observed position and find the actual speed and direction of the wind.

4.40 p.m. Over the W. Hinder Lt. and proceeded to carry out the order allowing 2 hours for your return to the W. Hinder Lt.
Find the compass courses out and back; when would you alter course to return, and what is the estimated position at this time?

(7)

9.0 a.m. Over Harwich, heading direct for Orford. Air speed 57 knots.

9.20 a.m. Over Shipwash Lt.
Give the actual direction and speed of the wind.

9.35 a.m. Altered course for the N. Hinder Lt.
Give the compass course, the estimated ground speed, and the angular drift.

10.5 a.m. Received orders to join a squadron leaving Sheerness at 10.10 a.m. for Zeebrugge. Air speed of squadron 60 knots.

10.10 a.m. Altered course to join the squadron.
Find the compass course and the time when you would expect to join the squadron.
Give also the estimated position where you would expect to join the squadron.

K. (*Chart*)

Give the latitude and longitude of the aircraft in each case and state whether the fix may be quite unreliable.

(1) Varne Lt. 78° Kentish Knock Lt. 60° W. Hinder Lt.
(2) N. Hinder Lt. 90° Cross Sands Lt. 53° Smith's Knoll Lt.
(3) W. Hinder Lt. 23° Kentish Knock Lt. 126° Steen Banks Lt.
(4) Kentish Knock Lt. 114° N. Hinder Lt. 90° Steen Banks Lt.
(5) Orford 30° Yarmouth 26° Cromer.
(6) Folkestone 32° Ramsgate 57° Orford.
(7) Cross Sands Lt. 40° Would Lt. 42° Smith's Knoll Lt.
(8) Dover 53° Harwich 51° Lowestoft.
(9) Calais 38° Ramsgate 47° Ipswich.
(10) Dunkerque 29° Calais 42° Ramsgate.

L

(For vivâ voce work)

Measurements.

How many feet are there in a statute mile?
What is a great circle? What is a true meridian?
What is meant by "the latitude of Greenwich is 51° 28′ N."?
What is meant by "the longitude of Boston, U.S.A., is 71° 8′ W."?
What is the magnetic meridian?
Explain the meaning of "the Variation is 12° W."
What is meant by stating "the desired track angle is 210° (mag)"?
How is the direction of the wind given?

Compass and Bearing Plate.

How is the compass card marked?
Why does not the compass needle generally point to Magnetic North?
What is (*a*) the lubber line, (*b*) the back lubber line?
What is meant by "the course was 330° (comp.)"?
How do you get the bearing of an object (*a*) when on the ground, (*b*) when in the air?
What deviation do you apply to the compass bearing of an object to obtain the magnetic bearing?

General.

Distinguish between (*a*) air speed and ground speed, (*b*) actual ground speed and estimated ground speed.
Distinguish between (*a*) desired track and estimated track,
(*b*) N.D. position and estimated position,
(*c*) estimated position and observed position.
Why is not the observed position always the same as the actual position?
How can you find the ground speed from observation?
Mention one or two ways of finding the observed position.
How can you estimate the direction and speed of the wind?
What is the angular drift?
Distinguish between estimated angular drift, and observed angular drift.
State how the Bearing Plate can be employed as a drift corrector.
Knowing your ground speeds out and home in a given direction, what is the formula for finding the time to turn, in order to get back in a certain time?
In intercepting a visible enemy, what principle will assist you as to whether you are steering the correct course?

Sea Work.

What is a nautical mile? How many feet are there in it?
How do you turn nautical miles into statute miles?
What is a knot? How will you turn m.p.h. into knots?
How many yards are there in a cable?
How many nautical miles are there in the equator?
What are the chief differences between a Mercator's chart and an ordnance survey map?
What scale do you use for measuring distances on a Mercator's chart?

Adjustment of the Compass.

What is a magnet? How can the influence of the earth on a compass needle be accounted for?
What is meant by saying that the "Dip at London is about 67°"?
Distinguish between permanent and induced magnetism.
How do you lay out a testing ground?
How do you determine the fore and aft line of the machine?
State briefly how you adjust the compass of an aeroplane.
Explain what is meant by "Swinging for Deviation."
Why will the compass not generally show the correct course when the machine is banked?
How is the reading of a turn affected in North Latitudes (*a*) if on a northerly course, (*b*) if on a southerly course?
Explain why in certain cases the compass may indicate a turn to the right when actually the machine has turned to the left.

Instruments.

What is the average pressure at sea level (*a*) in millibars, (*b*) in inches?
How does the pressure vary with the height?
Why does an altimeter not usually show the exact height above the ground?
In an air speed indicator, why are the readings too low at high levels?

Clouds.

When is air said to be saturated?
What is meant by saying that the relative humidity is 75 %?
State the four main types of clouds.
How are clouds formed?
What is the cause of "bumps" when flying? Give some examples.
How are land and sea breezes caused? How far from the coast are they experienced? At what heights do they generally cease to be noticeable?

Weather Map.

What is an isobar? What is the difference of pressure between consecutive isobars on the weather map?
What is meant by the wind (*a*) veering, (*b*) backing?
How does the wind alter with increased height?
What is the gradient wind? At what height may you expect it (*a*) over the land, (*b*) over the sea?
How can you find its speed from the isobars?

Depressions.

How does the air move with reference to the centre in (*a*) a "low," (*b*) a "high," in northern latitudes?
What is the usual track of a cyclonic depression in northern latitudes?
Explain the meaning of the word "trough."

SPECIMEN EXAMINATION PAPERS

INTERMEDIATE EXAMINATION. (*Map*)

Time, 1½ hours

(1) Explain what are meant by "Magnetic Meridian," "Deviation," "Compass Bearing."

Draw a line on the paper to represent the true meridian at a point O, draw the magnetic meridian at O for a variation of 15° E., and if your course is 60° (mag), show the direction of an object that bears 240° by compass, taking your deviation from the deviation table.

(2) Give the magnetic courses for compass courses of 10° and 190°. Give the compass courses for magnetic courses of 130° and 230°. An object bears 320° by compass when the compass course is 200°. Give the magnetic bearing.

(3) What is the "Lubber Line," and what is its use?

If an aeroplane is pointing 150° (mag), and the lubber line reads 145°, what is the deviation? Show by a figure whether it is East or West.

(4) An aeroplane was over Peterborough at 10.50 a.m. steering by the compass mark 23, air speed 80 m.p.h. At 11.10 a.m. she was over Northampton. Find the direction and speed of the wind.

(5) Find the compass course to set and the time required to fly from Boston to Oxford; air speed 90 m.p.h., estimated wind 30 m.p.h. from 150° (true).

If the wind was blowing directly from Oxford to Boston, how long would you take?

INTERMEDIATE EXAMINATION. (*Chart*)

Time, 1½ hours

(1) Give a rough rule for converting knots into m.p.h., and find in m.p.h. the equivalent of 86 knots. Measure the distance on the chart from N. Foreland to Zeebrugge, and find the number of minutes required to fly between these places if the ground speed is 72 m.p.h.

(2) Explain what is meant by "Magnetic North," "Compass North," "Compass Course."

(*a*) Compass Course is 105°, find the magnetic course.

(*b*) Magnetic Course is 220°, find the compass course.

(*c*) A machine was steering by the compass mark 15, and the compass bearing of a light was 50°, what is the magnetic bearing?

(3) At 1 p.m. you were over the Sunk Lt., estimated track angle 88° (mag), estimated ground speed 42 knots. At 1.30 p.m. you received a wireless message "Submarine reported in 52° 40′ N., 3° 10′ E." Give your estimated position at 1.30 p.m., and the track angle (mag) and distance to the submarine.

(4) Find the compass course and time taken from Harwich to Bruges, air speed 75 knots, wind from 345° (true), 20 knots.

(5) Explain the terms "Angular drift," "N.D. position."

When over Lowestoft the compass course was 185° and air speed 80 knots. After half an hour you are over Kentish Knock Lt. Find the direction and speed of the wind.

(6) In swinging for deviation the following results were obtained: find the deviation in each case.

Mag. Co.	Comp. Co.
N. 0°	2°
N.E. 45°	43°
E. 90°	87°
S.E. 135°	140°

FINAL EXAMINATION. (*Map*)

Time, 1½ hours

(1) Show by a figure the relative positions of:—

(*a*) The True and Magnetic Meridians, the Variation being 10° E.

(*b*) The Magnetic and Compass North, the Deviation being 5° W.

Using the table for converting Magnetic to Compass courses, give the compass courses corresponding to the magnetic courses 25°, 235°; and convert the compass bearing 155°, taken when the machine was flying 40° by compass, into magnetic.

(2) In flying from Hazebrouck (B 9) to Courtrai (F 8) give about five landmarks which you would select before going up as being likely to keep you on your desired track. Give the magnetic track angle and approximate time from the start to passing Menin taking the ground speed to be 90 m.p.h.

(*Map of N.W. Europe, Sheet* 1, *required.*)

(3) To determine the wind, a flight was made over Bedford to Cambridge. It was found that to keep to this track, the compass course that had to be steered was 110°. Bedford was passed over at 9.12 a.m. and Cambridge at 9.27 a.m. Mark the N.D. position at 9.27 a.m. and find the wind, the air speed being 92 m.p.h.

(4) Give the desired track angle (mag) and distance from Grantham to Oxford, and find the compass course to steer and the approximate time of arrival over Oxford, allowing for a wind of 35 m.p.h. from E. (true), and an air speed of 110 m.p.h. State the estimated angular drift.

(5) How far can you scout in a direction 220° (mag), returning to your starting point after 3½ hours? Wind from 330° (true) at 30 m.p.h., air speed 75 m.p.h. Variation 20° W.

(6) Flying from Oxford by the compass mark 4, at an air speed of 80 m.p.h., with an estimated wind from 40° (true), 20 m.p.h., show on the map the N.D. position and your estimated position after half an hour, and give the magnetic bearing and distance of Northampton at that time.

FINAL EXAMINATION. (*Chart*)

Time, 1½ hours

(1) Draw a rough figure to show the earth, the equator, the true meridian of Greenwich, and a place in lat. 30° N., long. 60° W.

What is the length of a nautical mile? Find the approximate time to fly 120 miles (taken from an Ordnance Survey Map), at a ground speed of 70 knots.

(2) What is meant by the statement "The deviation for the compass course 120° is 4° E."?

From an airship, flying about East (mag), the Cross Sands Lt. was observed to be in line with the Would Lt., both bearing 351° by compass. What was the deviation?

(3) Explain the terms "Magnetic Bearing" and "Angular Drift."

A disabled seaplane found that at 8 a.m. Kentish Knock Lt. bore 229° (comp.) and Sunk Lt. 316° (comp.). At 8.45 a.m. Sunk Lt. bore 274° (comp.) and Shipwash Lt. 325° (comp.). She was pointing about N.E. (mag) at both times. Plot her positions at these times, and give the direction and rate at which she is drifting on the sea.

(4) Explain the terms "Air speed" and "No Drift position."

It was found that to fly from Harwich to the Sunk Lt. the compass course was 130° and the time taken was 15 minutes, the air speed of the machine being 56 knots.

Find the wind, and hence determine the course to steer from the Sunk Lt. to Dunkerque, and the estimated ground speed.

(5) An airship leaves Dover at 6 a.m. with orders to scout as far as possible in the direction 70° (mag) and be back by 10 a.m. Her air speed is 40 knots, and the wind is given as 12 m.p.h. from 30° (true).

Find at what time she should turn and her scouting distance; give the latitudes and longitudes of her estimated positions at 8 a.m. and 9 a.m.

Wind and Weather. (*Final Examination*)

Time, ¾ hour

(1) What is the average pressure of the atmosphere at the sea level in millibars and in inches of mercury? How does it vary with the height?

Give the reason why the Air Speed Indicator reading should be corrected for height.

(2) State the four chief types of clouds, their approximate heights and appearances.

(3) (*a*) What would you estimate the wind to be at a height of 1000 feet when it is blowing at the surface from 45° at a speed of 20 m.p.h.?

(*b*) Estimate the gradient wind when the surface wind is from S. at 25 m.p.h.

(4) Show by sketches what "bumps" you might expect in flying

(*a*) over a reservoir on a hot sunny afternoon,

(*b*) over a ridge with the wind behind you.

(5) What do you mean by a cyclonic depression (or a "low")? State the general direction of the track of a cyclone over the British Isles.

If the cyclone is passing to the North of you, how does the wind shift?

State briefly the changes in the weather you would experience as it passes over you.

Wind and Weather. (*Final Examination*)

Time, ¾ hour

(1) What is the principle of the Altimeter?

Give the reason why it does not always show the correct height above the ground (neglecting any change of temperature).

What do you mean by "creep error"?

(2) Mention the three ways in which heat can pass from one place to another.

How are land and sea breezes caused?

About what distance from the coast are they experienced, and up to what height?

(3) Make sketches showing the air currents and what bumps might be expected in an aeroplane when passing

(*a*) from land to sea on a hot sunny afternoon,

(*b*) over a town with a number of factories.

(4) What do you mean by an anticyclone (or a "high")?

Make a rough sketch of the typical isobars, marking the direction of the wind at a few places.

What weather is usually associated with it?

At what time of the year is it frequently accompanied by fog?

WIND AND WEATHER. (*Final Examination*)

Time, ¾ hour

(1) Give the average pressure of the atmosphere at the sea level in millibars and inches. What would the barometer show on an average at 5000 feet?

What indication would decide you to estimate the wind as force 4 on the Beaufort Scale? State its probable speed at the ground; also at a height of 3000 feet.

(2) Name the chief cloud formations, with a *short* description of each type, and give several ways in which clouds can be formed.

(3) Show by sketches what bumps you would expect in flying

(*a*) over water warmer than the surrounding land,

(*b*) below a cumulus cloud.

(4) Draw a figure showing the arrangement of the isobars in a cyclone with a secondary depression, as usual in North latitudes. State briefly the weather likely to be experienced in the region of the secondary depression.

Exact coincidence with the answers given should not be expected

ANSWERS TO EXAMPLES

1. Pages 1, 2.

(1) 70; 49; 105; 44; 24; 660.
(2) 80; 72; 24; 103; 126; 46; 59.
(3) 21,600′; 240 hrs. (4) 2 h. 42 m. (5) 3 h. 26 m.

2. Page 4.

A. 48° N.; 30° E.
B. 20° S.; 60° W.
G. 51° N.; 0°.
K. 48° N.; 60° W.
L. 0°; 30° E.
M. 20° S.; 30° E.
O. 0°; 0°.
R. 0°; 60° W.

3. Page 5.

(1) 12½; 57; 50. (2) 81; 82; 100; 110.

4. Page 5.

(1) 52′; 38′; 56′. (2) 44′; 48½′; 58′; 72′.

5. Page 6.

(1) 64′. (2) 86′; 61′. (3) 63′; 23′. (4) 40′; 78′.
(5) 45′; 47′. (6) 77′; 151′. (7) 24′.

6. Page 7.

(1) 30 m. (2) 40 m. (3) 50 m. (4) 1⅓ hrs.
(5) 1 h. 16 m. (6) 54 m.

7. Page 7.

(1) 30 m. (2) 40 m. (3) 47 m. (4) 24 m.
(5) 1 h. 20 m. (6) 2 h.

8. Page 8.

(1) P, 0°; P′, 180°; D, 40°; E, 190°; F, 110°; G, 270°; H, 350°; K, 70°.
(2) X, 0°; Y, 50°; Z, 270°.

9. Page 12.

(1) 117°. (2) 200°. (3) 355°. (4) 352°. (5) 5°.
(6) 345°. (7) (*a*) 133°; (*b*) 13°; (*c*) 3°.

10. Page 13.

(1) 43°; 68°; 42 miles.
(2) 292°; 307°; 19 miles.
(3) 101°; 116°; 70 miles.
(4) 21°; 36°; 93 miles.
(5) 326°; 341°; 57 miles.
(6) 182°; 197°; 35 miles.
(7) 347°; 2°; 50 miles.
(8) 88°; 103°; 41 miles.

11. Page 13.

(1) 7°; 20°; 115′.
(2) 135°; 148°; 109′.
(3) 307½°; 320½°; 56′.
(4) 312½°; 325½°; 46′.
(5) 116½°; 129½°; 80′.
(6) 242°; 255°; 56′.
(7) 22½°; 35½°; 117′.
(8) 352½°; 5½°; 122′.

12. Page 14.

The lines should pass through the following towns:—

(1) Grantham. (2) Wisbech. (3) Northampton. (4) Oxford. (5) Peterborough. (6) Oxford. (7) Cambridge. (8) Bedford.

13. Page 15.

The lines should pass through the following places:—

(1) Kentish Knock Lt. (2) W. Hinder Lt. (3) Yarmouth. (4) Smith's Knoll Lt. (5) Middlekercke Lt. (6) Calais. (7) Smith's Knoll Lt. (8) Lowestoft.

14. Page 17.

(1) 49° (mag); 15 miles.
(2) 65° (mag); 47 miles.
(3) 111° (mag); 32 miles.
(4) 153° (mag); 31 miles.
(5) 213° (mag); 23 miles.
(6) 84° (mag); 46 miles.

15. Page 18.

(1) 275° (mag); 44′.
(2) 293° (mag); 76′.
(3) 134° (mag); 42′.
(4) 242° (mag); 42′.
(5) 219° (mag); 33′.
(6) 162° (mag); 47′.

16. Page 23.

(1) 0°; 205°; 248°; 338°; 72°; 108°; 281°; 230°; 254°; 350°; 151°; 240°.
(2) 0°; 204°; 18°; 301°; 27°; 342°; 226°; 36°; 351°; 243°; 113°; 235°.
(3) 184°; 230°; 175°; 69°; 59°; 346°; 5°; 307°; 121°; 159°; 248°; 77°.

17. Page 26.

(1) 75°. (2) 80°. (3) 290°. (4) 270°. (5) 0°. (6) 210°.

18. Page 29.

(1) (*a*) 26°. (*b*) 217°. (*c*) 5°. (*d*) 0°. (*e*) 358°. (*f*) 358°.
(2) (*a*) 241°; 30 miles. (*b*) 139°; 74½ miles. (*c*) 191°; 76 miles.
(3) (*a*) 51° 59′ N.; 1° 39′ E.; 216°; 68′.
(*b*) 51° 14′ N.; 2° 27′ E.; 206°; 11′.
(*c*) 50° 57′ N.; 1° 24′ E.; 69°; 47′.

19. Page 30.

(1) 4° E. (2) 2° W. (3) 1° E. (4) 7° E.

20. Page 31.

(1) 3° W. (2) 1° E. (3) 6° E. (4) 3° W.

21. Page 35.

(1) from 54° (mag); 25 m.p.h. (3) from 241° (mag); 45 m.p.h.
(2) from 106° (mag); 36 m.p.h. (4) from 110° (mag); 50 m.p.h.

22. Page 35.

(1) from 56° (mag); 15 knots. (3) from 226° (mag); 15 knots.
(2) from 144° (mag); 22 knots. (4) from 344° (mag); 35 knots.

23. Page 38.

(1) 60 m.p.h.; 9 miles. (3) 125 m.p.h.; 5 miles.
(2) 110 m.p.h.; 29 miles. (4) 50 m.p.h.; 10 miles.

24. Page 38.

(1) 65 knots; 52° 23′ N., 20° 32′ E.
(2) 65 knots; 50° 49′ N., 2° 23′ E.
(3) 54 knots; 51° 31′ N., 2° 28′ E.
(4) 59 knots; 52° 48′ N., 0° 48′ E.

25. Page 42.

(1) 71°; 51 m. (2) 62°; 52 m. (3) 191°; 48 m.
(4) 308°; 53 m. (5) 103°; 59 m.

26. Page 42.

(1) 115°; 41 m. (2) 165°; 1 h. 41 m. (3) 359°; 1 h. 57 m.
(4) 212°; 2 h. 18 m. (5) 150°; 1 h. 7 m.

27. Page 79.

(1) 0°, 9°, 18°, 27°, 37°, 47°, 57°, 68°, 79°, 90°, 101°, 112°, 123°, 134°, 144°, 153°, 162°, 171°, 180°, 189°, 198°, 207°, 216°, 226°, 237°, 248°, 259°, 270°, 281°, 292°, 303°, 314°, 324°, 333°, 342°, 351°.

(2) 5°, 14°, 23°, 32°, 41°, 50°, 60°, 70°, 80°, 90°, 99°, 108°, 117°, 126°, 135°, 146°, 157°, 168°, 179°, 192°, 205°, 219°, 233°, 243°, 249°, 256°, 263°, 270°, 279°, 288°, 297°, 306°, 316°, 328°, 340°, 352°.

28. Page 88.

(1) (*a*) from 165° (true), 40 m.p.h.
(*b*) from 170° (true), 40 m.p.h.
(2) (*a*) from 200° (mag), 22 m.p.h.
(*b*) from 190° (mag), 15 m.p.h.
(3) (*a*) from 0° (true), 30 m.p.h.
(*b*) from 10° (true), 40 m.p.h.
(4) from 350° (true), 10 m.p.h.
(5) from 250° (mag), 27 m.p.h.

29. Page 94.

At A	20	m.p.h.	or 16	knots.
B	30	,,	,, 25	,,
C	40	,,	,, 32	,,
D	16	,,	,, 13	,,
E	10	,,	,, 8	,,
F	10	,,	,, 8	,,
G	15	,,	,, 12	,,
H	12	,,	,, 10	,,
I	23	,,	,, 20	,,

ANSWERS TO APPENDIX OF EXAMPLES

A_1

(1) 333° (mag); 25 miles.
(2) 52 miles.
(3) 32 miles.
(4) 172° (mag); 37 miles.

A_2

(1) 51° 35′ N., 1° 49′ E.; 40′.
(2) 52° 41′ N., 2° 18′ E.; 23′.
(3) 24′.
(4) 10 m.

B_1

(*Directions are magnetic*)

(1) from 31°; 42 m.p.h.
(2) from 225°; 20 m.p.h.
(3) from 236°; 40 m.p.h.
(4) from 196°; 30 m.p.h.
(5) from E.; 40 m.p.h.
(6) from 332°; 38 m.p.h.
(7) from 9°; 30 m.p.h.
(8) from 244°; 22 m.p.h.
(9) from 64°; 23 m.p.h.
(10) from 356°; 18 m.p.h.
(11) from 272°; 40 m.p.h.
(12) from 323°; 42 m.p.h.

B_2

(*Directions are true*)

(1) from 180°; 20 knots.
(2) from 333°; 22 knots.
(3) from 187°; 10 knots.
(4) from 274°; 36 knots.
(5) from 103°; 42 knots.
(6) from 207°; 21 knots.

C_1

(1) 98° (mag); 51 m.p.h.
(2) 301° (mag); 61 m.p.h.; 19°.
(3) 53 m.p.h.; 26°.
(4) 38°; 57 m.p.h.
(5) 6 miles.
(6) from 288° (true); 34 m.p.h.
(7) from 195° (mag); 44 m.p.h.
(8) from 104° (true); 7 m.p.h.
(9) from 100° (true); 29 m.p.h.

C_2

(1) 51° 43′ N., 2° 38′ E.; 88 knots.
(2) 51° 48′ N., 1° 46′ E.; from 250° (mag), 18 knots.
(3) from 102° (mag), 31 knots. 51° 25′ N., 2° 46′ E.
(4) from 257° (mag), 35 knots. 51° 17′ N., 2° 11′ E.
(5) Est. pos. 2.50 p.m. 52° 34′ N., 2° 1′ E.; from 218° (mag), 21 knots; 52° 31′ N., 2° 23′ E.

D₁

	Compass course	Ground speed	Time
	°	m.p.h.	h. m.
(1)	333	54	49
(2)	225	124	27
(3) (a)	104	85	1 25
(b)	74	44	57
(c)	304	47	1 4
(d)	3	62	2 58
(4) (a)	120	75	58
(b)	353	68	1 4
(c)	18	52	2 7
(d)	211	95	1 10
(5)	216	36	1 39
(6)	24	100	30
(7)	347	94	57
(8)	90	87	37
(9)	72	88	42
(10)	210	5	3 9
(11)	130	47	—
(12)	Yes 317	87	48
(13)	205	73	41
	316	58	1 4
(14)	45	55	1 15
	310	75	34
	197	119	27
			Total 2 20

D₂

	Ground speed	Compass course	Time
	Knots	°	h. m.
(1) (a)	64	153	39
(b)	86	133	56
(c)	43	50	1 42
(d)	52	105	1 28
(2)	55	157	25
(3)	67 out	216 out	33
	61 back	2 back	36
(4)	71	48	44
(5)	71	48	44
	84	89	24
	63	270	1 16
			Total 2 24
(6)	56	212	1 0
		8° to left	
(7)	68	33	29
	Wind from 338° (mag), 34 knots		
(8)	70	59	34

E_1

(1) 16°.
(2) 13°.
(3) 8°.
(4) 15°.
(5) 80°.
(6) 8° (to left); 356°.
(7) (*a*) 5° to left; 190°.
(*b*) 3° to left; 127°.
(*c*) 10° to right; 16°.
(*d*) 6° to right; 6°.
(*e*) 4° to left; 204°.
(*f*) 5° to left; 45°.
(*g*) 6° to right; 346°.

E_2

(1) 19° to the left; 160°.
(2) 15° to the right; 151°.
(3) 8° to the left; 182°.

F_1

(1) 117°; 1 h. 53 m.
(2) 88° (mag); 53 m.
(3) 118°; 1 h. 30 m.
(4) 73°; 1 h. 40 m.
(5) 86°; 47 m.
(6) 46 m.; 159°.
(7) 268°; 34 m.
(8) 316°; 45 m.
(9) 46°; 9 h. 49 m. a.m.
(10) 53°; 39 m.
(11) 357°; 11 h. 11 m. a.m.
(12) 16°; 3 p.m.

F_2

(1) (*a*) 77°; 43 m.
(*b*) 13°; 56 m.
(*c*) 195°; 0 h. 59 m.
(*d*) 81°; 42 m.
(*e*) 210°; 1 h. 16 m.
(2) 169°; 25 m.
(3) 160°; 1 h. 10 m.
(4) 352°; 39 m.
(5) 51°; 9 h. 47 m. a.m.
(6) 136°; 3 h. 56 m. p.m.

G_1

(1) 75°; 21 m.
(2) 122°; 29 m.
(3) 252°; 33 m.
(4) 151°; 20 m.
(5) 306°; 34 m.

G_2

(1) 52°; 10 h. 41 m. p.m.
(2) 83°; 7 h. 37 m. a.m.
(3) 14°; 8 h. 33 m. p.m.
(4) 81°; 10 h. 19 m. p.m.
(5) 77°; 10 h. 6 m. p.m.

H_1

	Comp. course		Ground speed		Time to turn	Scouting range
	Out	Home	Out	Home		
	°	°	m.p.h.		h. m.	Miles
(1)	—	—	55	105	1 58	108
(2)	—	—	122	62	1 21	164
(3)	108	290	63	103	2 10	137
(4)	33	205	135	75	1 26	193
(5)	57	288	51	72	2 59	148
(6)	311	122	20	100	4 9	83
(7) (*a*)	178	0	72	72	1 30	108
(*b*)	178	0	42	102	2 8	89
(*c*)	178	0	102	42	52	89
(8)	275	141	69	38	1 27	102
(9)	260	100	98	60	45	75
(10)	249	125	80	80	2 0	160 } 20 miles
	99	281	47	137	2 59	140 }
(11) (*a*)	0	178	55	155	2 13	122
(*b*)	178	0	155	55	47	122
(*c*)	65	297	92	92	1 30	139
(12) (*a*)	218	59	79	20	1 37	129
(*b*)	59	218	20	79	6 23	129
(*c*)	102	354	35	45	4 30	157
(13) (*a*)	61	180	84	84	1 15	104 30° or 210°
(*b*)	117	299	50	140	1 50	92 300° or 120°
(14)	334	119	68	78	2 10	143
(15)	210	18	95	53	1 3	101
(16)	92	222	57	82	1 35 p.m.	33
(17)	63	205	66	127	1 19	86
(18)	112	331	82	40	7 49 p.m.	67

H_2

	Comp. course		Ground speed		Time to turn	Scouting range
	Out	Home	Out	Home		
	°	°	Knots		h. m.	Sea miles
(1) (*a*)	84	203	54	88	3 45	198
(*b*)	146	287	34	96	3 41	127
(*c*)	206	348	34	77	2 46	95
(*d*)	302	87	60	90	3 36	220
(2)	71	291	80	50 }	11 46 a.m.	61
					52° 51′ N., 3° 20′ E.	
(3)	95	266	52	107 }	1 21	70
					52° 45′ N., 3° 35′ E.	
(4)	116	309	103	56	4 42 p.m.	73
(5)	127	261	89	72 }	39	60
					6′ from Zeebrugge	
(6)	48	238	108	90 }	5 49 a.m.	196
					4.18 a.m. and 7.38 a.m.	

I_1

	Comp. course		Ground speed		Time to turn	Scouting range
	Out	Home	Out	Home		
	°	°	m.p.h.		h. m.	Miles
(1)	33 (mag)	262 (mag)	82	50	2 0	165
(2)	329	44	47	43	1 31	71
(3)	141	283	85	40	3 34 p.m.	134
(4)	15	308	60	47	1 10	16 from Wisbech
(5)	315	25	65	46	27	30
(6)	110	1	56	31	1 2	58
(7)	4	102	64	25	1 4	69

I_2

	Comp. course		Ground speed		Time to turn	Scouting range
	Out	Home	Out	Home		
	°	°	Knots		h. m.	Sea miles
(1)	140	298	65	53	1 32	100
(2)	42	260	45	62	1 58	90 [4.38 p.m.]
(3)	41	269	87	45	11 12 a.m.	105
(4)	113	231	82	45	1 18	107
(5)	25	134	96	62	8 40 a.m.	112
(6)	130	69	59	41	9 55 a.m.	54 [14′ from Dunkerque]
(7)	74	295	72	101	10 37 a.m.	44

J_1

(1) Wind from 167° (mag), 32 m.p.h.; 16°; 89 m.p.h.
Compass course 83°; 105 m.p.h.; 5 h. 30 m. p.m.; 14 miles.

(2) Wind from 64° (mag), 30 m.p.h.; Course 10° (comp.); 8 h. 50 m. p.m.

(3) Wind from 136° (mag), 24 m.p.h.; Compass course 182°; 53 m.p.h.; 4 miles.
3° to the right; Course 185° (comp.); 16 miles.

(4) Course 12° (comp.); wind from 270° (mag), 10 m.p.h.
Compass course 347°; 86 m.p.h.; 10 h. 11 m. p.m.; Deviation 0°.

(5) Wind from 263° (mag), 30 m.p.h.; Compass course 0°; 93 m.p.h.; 19°.
Observed drift 18°; 6° to the right.
(6) Wind from 230° (mag), 17 m.p.h.; Compass course 273°; 72 m.p.h.; 9°.
Compass course 211°; 66 m.p.h.; 4 h. 40 m. p.m.
(7) Compass course 129°; 77 m.p.h.
Corrected course 99° (comp.); 7 h. 8 m. p.m.
(8) Wind from 44° (mag), 27 m.p.h.; Course 2° (comp.); 11 h. 42 m. p.m.

J_2

(1) From 80° (mag), 27 knots; 138°; 1 h. 27 m. p.m.
(2) From 299° (mag), 27 knots; 228°; 10 h. 49 m. a.m.
(3) 51° 49′ N., 1° 34′ E.; from 74° (mag), 28 knots; 132°; 8 h. 5 m. a.m.
(4) 51° 45′ N., 1° 35′ E.; from 343° (mag), 14 knots; 11 h. 16 m. a.m.
Est. pos. 11.25 a.m. 52° 8′ N., 2° 53′ E.; 283° (gr. sp. 59 knots); 12 h. 36 m. p.m.
(5) 52° 43′ N., 2° 45′ E.; from 87° (mag), 29 knots.
Est. pos. 1.45 p.m. 52° 41′ N., 2° 29′ E.; 191°; 2 h. 23 m. p.m.
336°; 3 h. 30 m. p.m.
(6) 51° 15′ N., 2° 29′ E.; from 247° (true), 28 knots; 5°; 216°; 5 h. 27 m. p.m.; est. pos. 52° 22′ N., 2° 44′ E.
(7) From 338° (mag), 28 knots; Compass course at 9 h. 35 m. a.m. 87°; 72 knots; drift 22°.
Compass course at 10 h. 10 m. a.m. 257°; 11 h. 2 m. a.m.
Est. pos. 51° 22′ N., 2° 27′ E.

K

(1) 51° 6′ N., 2° 10′ E.
(2) 52° 41′ N., 2° 30′ E.
(3) No fix.
(4) 51° 46′ N., 2° 32′ E.
(5) 52° 44′ N., 2° 38′ E.
(6) 51° 15′ N., 1° 58′ E.
(7) 52° 45′ N., 2° 20′ E. (poor fix).
(8) 51° 52′ N., 2° 24′ E.
(9) 51° 33′ N., 2° 32′ E.
(10) No fix.

Examination Papers

Intermediate (Map)

(1) 237° (mag).
(2) Mag. course 9°; 194°. Compass course 126°; 224°. Mag. bearing 325°.
(3) 5° E.
(4) From 94° (mag), 31 m.p.h.
(5) Compass course 205°; gr. sp. 72 m.p.h.; Time 1 h. 21 m.; 1 h. 38 m.

Intermediate (Chart)

(1) 98 m.p.h.; 67′; 56 m.
(2) (*a*) 107°. (*b*) 214°. (*c*) 54°.
(3) 51° 58′ N., 2° 10′ E.; 55°; 56′.
(4) 120°; 58 m.
(5) From 44° (mag), 25 knots.
(6) 2° W.; 2° E.; 3° E.; 5° W.

Final (Map)

(1) Compass course 28°; 230°. Mag. bearing 151°.
(2) 90°; 17 m.
(3) From 206° (mag), 33 m.p.h.
(4) 214°; 82 miles; 193° (comp.); 42 m. 18°.
(5) 116 miles.
(6) 87°; 9 miles.

Final (Chart)

(1) 1 h. 30 m.
(2) 3° W.
(3) 52° (mag), 4 knots.
(4) From 207° (mag), 16 knots; Compass course 172°; gr. sp. 44 knots.
(5) Out 63° (mag), 31 knots; Home 257° (mag), 49 knots; scouting range 76′; turn at 8 h. 27 m. a.m.
8 a.m. 51° 41′ N., 2° 40′ E.
9 a.m. 51° 35′ N., 2° 24′ E.

INDEX

CAMBRIDGE: PRINTED BY J. B. PEACE, M.A., AT THE UNIVERSITY PRESS.